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SURGERY

ITS PRINCIPLES AND PRACTICE

BY VARIOUS AUTHORS

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VOLUME V

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POSTSCRIPT

In issuing the last volume of this work the editors extend their hearty thanks to all the nearly seventy collaborators by whose zeal and ability it has been made possible. In the midst of the incessant demands of strenuous lives they have given of their best, often, as the editors well know, at the expense of comfort, recreation, and sleep.

Two have relinquished their earthly labors: Lennander, who completed part of his work, and Mikulicz, who had not even had the opportunity to begin his task. Not only as authors, but as warm personal friends, the editors sincerely mourn their loss.

The departures from the order of the chapters as originally planned have been necessitated in some cases by serious illness, but more commonly by the exigencies of extremely busy lives. Men with ample leisure would hardly have performed the task satisfactorily.

The prospectus promised five volumes of 800 pages each, 4000 pages in all, but the completed work covers nearly 5500 pages (to say nothing of the large increase in the amount of text from using smaller type in certain parts), an increase of over 25 per cent., without any increase in price.

To the artists, the publishers, and their employés, for their unfailing courtesy and efficient aid, the warm thanks of both editors and authors are tendered.

William W. Keen.

Philadelphia, Pa., October, 1909.

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SURGERY

ITS PRINCIPLES AND PRACTICE.

CHAPTER LXX.

SURGERY OF THE VASCULAR SYSTEM.

By Rudolph Matas, M. D.,

NEW ORLEANS.

I. Surgery of the Pericardium and the Heart.

SURGERY OF THE PERICARDIUM.

Historic Memoranda.—In 1648 Riolan first suggested drainage of the pericardial sac and recommended that the lower end of the sternum be trephined for the purpose. In 1798, a century after, Desault and Larrey independently attempted to evacuate the pericardial sac by different routes, the latter by the left costoxiphoid space, but failed in both instances because of mistaken diagnosis. Laënnec in 1819 greatly contributed, by his powerful influence, in encouraging pericardiotomy. He advised Riolan's plan of trephining the sternum at the xiphoid cartilage. The first successful pericardiotomy was performed by Romero, of Barcelona, in 1819, who incised the chest in the fourth and fifth interspaces near the sternum. He saved two patients. The great epidemic of scurvy in Cronstadt and the Baltic provinces gave numerous opportunities to Russian surgeons (Karaneff, Kyber, et al.) to tap the pericardium for the relief of hemorrhagic pericarditis. In 1854 Trousseau and Lasègue greatly aided in the establishment of this operation by their influential advocacy.

The method of puncture and aspiration supplanted all other methods of puncture in France and other countries after 1869, in consequence of the eloquent representations of Dieulafoy in France. Bowditch, of Boston, likewise influenced the profession in America. Wheelhouse, of Leeds (1866); West (1882), in England; J. B. Roberts (1876–97), America; Rosenstein and Hindenlang (1879), in Germany, firmly established the value of pericardicentesis as a curative procedure in their respective countries.

With the advance of asepsis, a tendency to return to the open methods of incision is everywhere noticeable. The greater safety of aseptic open pericardiotomy over the uncertainties of puncture, with its risk of injuring the heart, is urged by J. B. Roberts, C. B. Porter, Stephen Paget, von Eiselsberg, Kocher, Allingham, Pendlebury, and other surgeons, and this mode of procedure gains ground gradually but surely.

Surgical Anatomy.—The Pericardium.—The outline of the pericardium is that of a truncated cone, with the apex pointing upward

and with the base resting on the diaphragm. The base is directed slightly downward and to the left. The line of the base crosses the ensiform cartilage at its junction with the sternum, commencing 2 cm. to the right of the right sternal border, and ends 6 to 8 cm. (3 to 4 inches) to the left of the sternum, in the fifth interspace. The right border of the pericardium may be indicated by a slightly convex line going outward and upward, from the beginning of the base line on the right of the sternum, reaching a point 1 to 2 cm. to the right of the sternum on a level with the second right costal cartilage. It then approaches the sternum and is lost behind it on the left side. The left lateral outline of the pericardium begins inferiorly at the left end of the base line, in the fifth interspace, and ascends obliquely upward to a point slightly to the outside of the left sternoclavicular articulation. The two lateral boundaries of the pericardium thus indicated would, if prolonged from this last point downward, meet on a level in the right second intercostal space, at the sternal junction. The anterior layer of the peri-

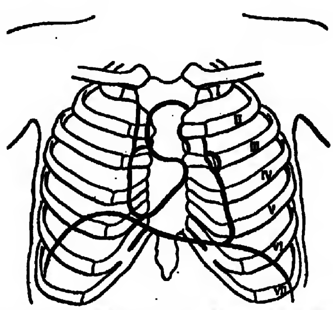

FIG. 1.—OUTLINE OF THE HEART AND AORTA ON THE ANTERIOR WALL OF THE THORAX. (Terrier and Reymond.)

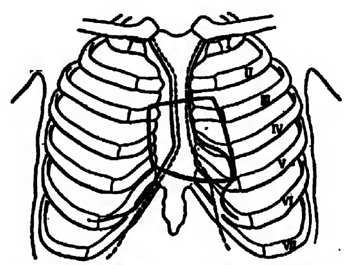

FIG. 2.—OUTLINE OF HEART, PLEURA, AND LUNGS, SHOWING THE INTERPLEURAL PERICARDIAL SPACE. (Terrier and Reymond.)

cardium is separated (in the anteroposterior plane) from the sternum above by an interval of 3 to 5 cm.; below, by a thickness of 1 cm. While the pericardial serosa is everywhere brought in intimate contact with the heart (Poirier), and is in constant touch with it, so that it follows all its movements, it also forms several duplications or culs-de-sac at various points, which become distended when effusions fill the pericardial sac. Of these, the anterior lower cul-de-sac is of surgical importance in tapping the pericardium, as we shall see later. At the diaphragmatic plane of attachment, on a line with the costophrenic angle, it is folded on itself for a distance of 1 to 2 cm. It is possible to perforate the pericardium at this point without touching the heart. The parietal reflections at the base of the heart follow the course of the great blood-vessels in an irregular line, which attains its greatest height at a point corresponding to the posterior surface of the origin of the right innominate. This would be about the middle of the manubrium sterni. The aorta, up to the origin of the innominate, and the pulmonary artery, up to its bifurcation, are enveloped by the pericardial

serosa. Injury to these vessels would be followed by an immediate hemorrhage into the pericardium. The pericardium is of variable thickness,—usually 1 mm.,—sometimes much thinner. It is of a white dull color, by which it can be distinguished readily from the pleura, which is translucent.

The Internal Mammary Artery.—The internal mammary arteries are usually described as passing perpendicularly downward from their origin in the subclavian on each side of the sternum behind the cartilages of the ribs, about one-half inch outside of the sternal margin. The tendency of each artery is to depart slightly from the margin of the sternum from above downward. Voinitch-Sianojentzky, after a careful study of many cadavers, state that the *average* distance of the artery in the fourth interspace is 1.6 cm.; in the fifth, 2 cm.; in the sixth, 2.5 cm. As these are the most important interspaces from the surgical point of view, we need not consider the other relations of the artery.

The Anterior Pleural Culs-de-sac.—These follow a direction which is variable in normal individuals, and is made still more irregular

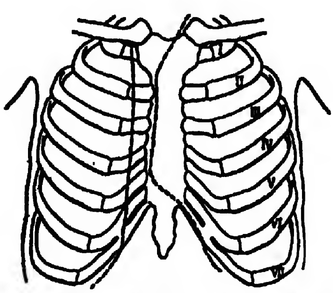

FIG. 3.—ANOMALOUS VARIATIONS IN THE POSITION OF THE LEFT PLEURA. (Terrier and Reymond.)
The left pleura is shown crossing the middle line.

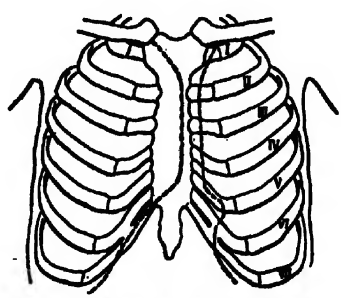

FIG. 4.—ANOMALY OF RIGHT PLEURA. (Terrier and Reymond.)
It is shown crossing the median line.

by pathologic conditions which involve the lungs and chest-walls in various ways, and from other causes. It is in regard to this part of the topography of the chest that the differences between authors are most marked. (See Dr. Irving Haynes' paper.) The discrepancies are due, according to Voinitch, to—(1) The great frequency of *normal* individual variation; (2) the greater frequency of *pathologic* variations which influence the anterior attachments of the pleura; (3) to the diversity of methods employed in making the investigation. According to Bochdalek, out of fifteen adult subjects, not one was found with perfectly normal pleuræ. The study of the relation of the pleura to the chest-wall is very important to the operator who is interested in avoiding the pleura while puncturing or opening the pericardium, in draining the sac, or when operating on the heart. The fear of septic infection of the pleura while puncturing or incising the pericardium in

pus cases, also of causing surgical pneumothorax accidentally, justifies the great importance attached to the subject. Voinitch-Sianojentsky calls attention to the fact that the topographic relations of the pleura to the chest-wall and the pericardium are influenced by a variety of pathologic conditions. Thus, adhesions in the *right* pleural cul-de-sac draw it toward the right side; adhesions in the *left* pleural cul-de-sac draw it toward the left; adhesions in *both* pleural culs-de-sac cause a retraction of *both* pleuræ and increase the width of the interpleural space, thereby uncovering the surface of the pericardium in the anterior mediastinum to a larger extent. The older the adhesions, the more fixed and extensive they are, the greater their influence in retracting the pleural borders. In addition, pleural effusions, pulmonary lesions—emphysema especially; scoliosis, marasmus, abdominal tumors, ascitic accumulations; cardiac hypertrophy and dilatation and pericardial effusions all change the normal relations of the pleural sacs to the anterior mediastinum, and contract or enlarge the free pericardial interpleural space. Contrary to the views of other authorities, Voinitch believes that in pericardial effusions the interpleural space is widened, and that the floor of the sac is lower and displaced anteriorly, so that the anterior pericardial cul-de-sac descends between the diaphragm and the thoracic wall. According to his view, the lowest point of drainage would be on a level with the sixth left costal space.

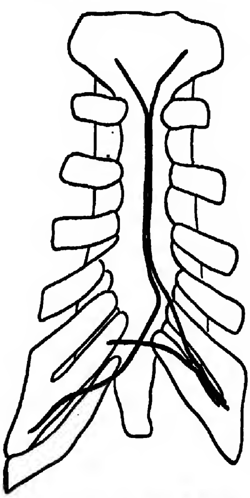

FIG. 5.—"TRIANGLE OF SAFETY" OF VOINITCH AND SIANOJENTSKY. (Terrier and Reymond.)

The Anterior Mediastinum or the Interpleural Space; the Uncovered Pericardial Triangle of Voinitch-Sianojentsky.—By making a composite study of a series of superimposed tracings of the anterior pleural margins taken from normal subjects, Voinitch was able to obtain the outline of a small, irregularly triangular space, which represented the pleura-free or uncovered surface of the pericardium. The long axis of the space lies 1½ cm. to the left of the middle line of the sternum, and runs parallel with the vertical line drawn through the seventh left chondro-sternal articulation. This triangle is bounded above by a horizontal line which crosses the lower border of the fifth chondro-sternal articulation, and below by another horizontal line which crosses the seventh chondro-sternal joint and the base of the xiphoid cartilage. An exploring needle introduced directly forward into the sixth interspace, close to the sternal margin, will penetrate the pericardium without injuring the pleura or touching the mammary vessels, and will drain the antero-inferior pericardial cul-de-sac where the accumulations are always present when a patient is in a semi-recumbent position. This spot we shall henceforth refer to as Voinitch's "triangle of safety."

Lungs.—From the sternal ends of the clavicle the lungs converge so that their thin edges meet in the mesial line, on the level with the second costal cartilage. From the level of the second costal cartilage to the fourth the margins of the lungs lie parallel or nearly so, close behind the middle of the sternum. Consequently their thin edges overlap the great vessels and the valves at the base of the heart. Behind the level of the *fourth* costal cartilage the margins of the lungs diverge, but not equally. The margin of the right follows the direction of the cartilage of the sixth rib; the margin of the left lung is notched for the heart, and runs behind the cartilage of the fourth rib. A line drawn perpendicularly from the liver would find the lower lung-margin about the lowest part of the sixth rib (Holden). In deep inspiration the lung-margins descend about 1½ inches. In children the lungs are separated in front by the thymus; about the approach of puberty this gland disappears.

For clinical purposes Latham's description of the uncovered cardiac area (least resonant to percussion) is valuable: "Make a circle of 2

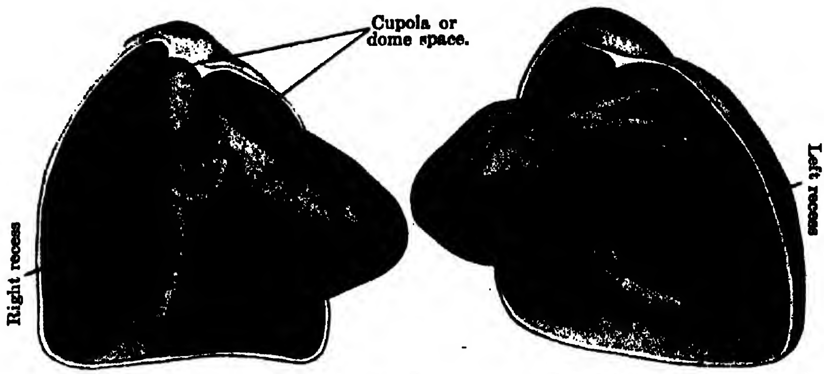

FIG. 6.—RECESSES AND POCKETS IN THE PERICARDIAL SAC WHEN DISTENDED BY FLUID. (Rehn.)

inches in diameter around a point midway between the nipple and the left lower end of the sternum. The circle will define, for all practical purposes, that part of the heart which lies immediately behind the wall of the chest and is not covered by lung or pleura."

The quantity of liquid that the pericardium may contain is quite variable—often one quart, but in very exceptional cases it has been found to contain as much as four liters or about one gallon.

Relationship Between the Heart, the Pericardium, and its Fluid Contents, when Effusions Exist in the Sac.—The distribution of the fluid contained in the distended pericardium has important practical bearings, not only upon the technic of paracentesis and pericardiotomy, but also upon the interpretation of the phenomena of heart-compression in progressive exudations or hemorrhagic extravasations, as we shall point out later in dealing with heart wounds. The old view held by Skoda and his followers that the heart was suspended from the great vascular trunks at the summit of the pericardium, and that when

fluid accumulated in the serosa it always gravitated downward and forward, displacing the heart backward and floating it upward, is no longer tenable in the light of more recent and careful researches and observations. Schaposchnikoff, Curschmann, Voinitch, Rehn, etc., teach that the heart is pushed upward anteriorly, and may be in contact with the anterior wall. Others contend that the heart remains in its normal position (see authors quoted by Calvert), and that its normal position is not altered until myocardial compensation fails. According to Calvert, when compensation fails, the heart becomes smaller and smaller until collapsed, when it is driven backward with the increasing intrapericardial tension against the posterior

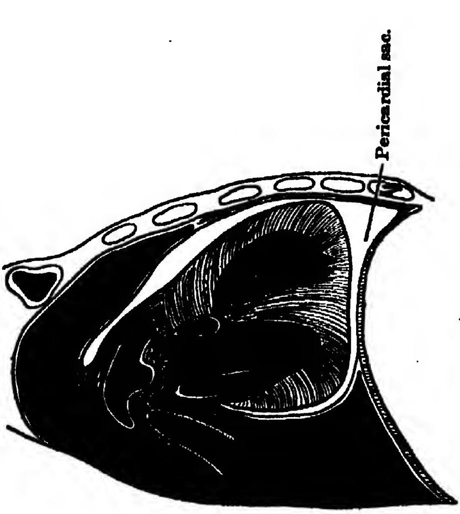

FIG. 7.—MESIAL SECTION SHOWING RELATIONS OF HEART TO PERICARDIAL SAC IN PERICARDIAL EFFUSION; SUBJECT LYING HORIZONTALLY. (Voinitch.)

Appearance when the pericardium contains 400 grams of liquid.

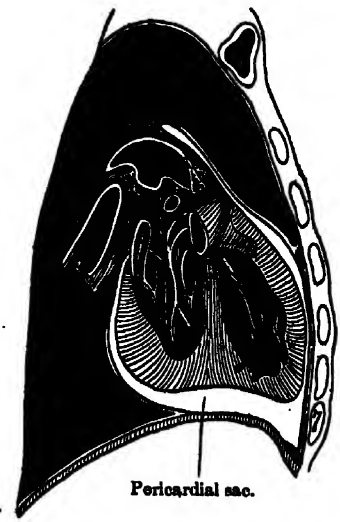

FIG. 8.—THE PERICARDIUM CONTAINS 400 GRAMS, THE SUBJECT SITTING UP. (Voinitch.)

Note accumulation of fluid in the dependent parts, especially in the anterior costo-phrenic sinus or pocket.

wall of the pericardium. There appears to be no difficulty in accepting the view that the position of the heart is practically normal as long as myocardial compensation exists; but the opinion expressed by Calvert, based upon the observation of two injected cadavers, is at variance with the most recent experimental and clinical experience.

The latest experimental and clinical evidence furnished by surgeons who have opened the pericardium in living subjects and noted the disposition of the contained fluid and the relationship of the heart to the chest-wall (Rehn, Brentano, Riedel, *et al.*) confirms the facts brought out long ago by Curschmann, Schaposchnikow, Voinitch-Sianojentzky, and others (Figs. 7 to 10), that the fluid primarily accumulates in the two postero-lateral pouches of the pericardium on each side of the middle partition formed by the rigid, unyielding projection of the

vena cava superior and inferior and the intermediary right auricle to which they are attached. Subsequently the fluid collects in a dome-shaped space defined transversely by the pulmonary vein and bounded above by the distended reflection of the serosa at the point where it is attached to the aorta and the innominate artery. When the pericardium is distended by fluid, these three compartments—right, left, and upper—are well defined by the middle vertical partition formed by the vena cava and by the transverse projection formed by the pulmonary vein (Rehn). In large effusions the diaphragm is also displaced downward, and the anterior costo-phrenic sinus, which is only a potential space in normal conditions, becomes distended by the accumulated fluid. The heart, lying immersed in this fluid bed, cannot be displaced backward on account of its fixed and immovable attachments,

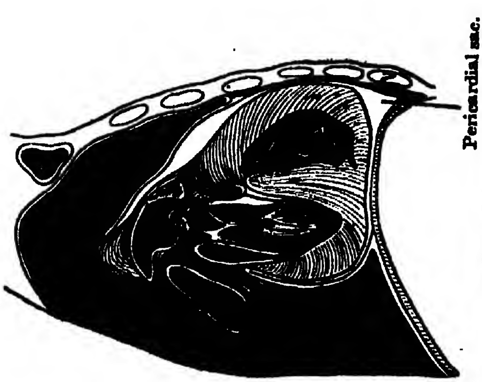

FIG. 9.—THE PERICARDIUM HAS BEEN INJECTED WITH 40 GRAMS OF FLUID, THE SUBJECT LYING DOWN. (Voinitch.)

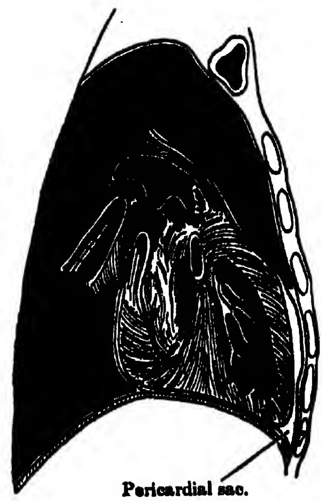

FIG. 10.—THE PERICARDIUM CONTAINS 40 GRAMS OF FLUID, THE SUBJECT IN THE ERECT POSITION. (Voinitch.)

at its base, to the vena cava, but its apex and movable ventricles are crowded forward toward the anterior chest-wall by the fluid which has accumulated in the postero-lateral pouches and upper dome-like compartment; also slightly upward by the fluid which gravitates into the costo-phrenic angle. The distended pericardium cannot expand backward, behind the heart, on account of the resistance of the vertebral column; or forward, because the thoracic wall is in the way. It can only expand and stretch laterally at the expense of the lungs and other yielding intrathoracic organs. Hence in the great effusions which cause heart-pressure-signs the distended lateral sacs stretch out laterally—beyond the right margin of the sternum, where the fluid can be easily tapped—or to the left of the mammary line, and beyond it, where a trocar can enter without approaching the heart itself. A

capital fact that results from all this discussion is that the heart is progressively crowded forward, always approaching the chest-wall more closely as the tension of the pent-up fluid increases. Consequently the normal precordial area is the most dangerous of approach; not only is there no fluid, or very little, to tap in front of the heart, but the organ blocks the way to the accumulation which lies behind it. This forward crowding of the heart by pericardial extravasations and effusions has been noted by surgeons in operations for heart wounds, as well as for the relief of pericardial effusions. It has been noticed that the heart, unless held by adhesions, immediately drops back into the mediastinum the moment the pericardial tension is relieved by the incision which releases the fluid. In fact, it is a problem in heart-wounds which require suture how to bring back the heart to the surface where it will be most accessible to the surgeon.

Pericardicentesis (Paracentesis Pericardii).—Selection of the Site of Puncture, and Technic.—In preparing to puncture or tap the pericardial sac, either for exploratory or therapeutic purposes, the operator should select that site for the introduction of the exploring needle which will give the patient the greatest security from—(1) Injury to the mammary vessels; (2) injury to the pleura; (3) injury to the heart itself; and, at the same time (4) provide a certainty of reaching the largest collection of fluid in the most favorable position for aspiration and drainage or, if necessary, incision. The surgeon should provide himself also with such instruments or apparatus which will be certain to demonstrate the presence of the fluid if it exists in quantities sufficient to justify the operation. That these desiderata have not been satisfied fully by any of the single methods thus far proposed is shown distinctly by the vast number of suggested "typical" points of puncture, or of "election," which crowd the literature of the subject and bewilder the judgment of the student and the operator. In order to arrive at some conclusion as to the best point for puncture, we will consider seriatim the desirable conditions which are to guide us in making our choice:

(1) The internal mammary vessels. The importance of avoiding these has been so fully recognized that the position of the internal mammary has been taken as a basis for the classification of the typical points of puncture, which may be divided into—(*a*) puncture *inside* of, and (*b*) *outside* of, the mammary vessels. The position of these vessels has been so well recognized that of all the accidents which have been recorded as occurring in this operation, injuries to these vessels are the least frequent. In accordance with the above division we find that all the intercostal spaces from the third left to the seventh left costal cartilage have been selected at some time or other, for puncture either close to the outer margin of the sternum *inside* of the mammary vessels, or *outside* of these.

The accompanying diagram will give some idea of the diversity of opinion as to the so-called point of election in paracentesis pericardii:

A. Third intercostal space (Schuh and Sharp).
Fourth intercostal space (Karanajew; Pirogoff; Champouillon).
Fifth intercostal space (Roger, Aran, Heger, Baizeau, Ferrand, West, Wilson, and J. B. Roberts—for septic cases).
Fourth or fifth intercostal space (Sievers, Dieulafoy, Rosenbach).
Sixth intercostal space (Hobart A. Hare; Delorme and Mignon; Voinitch-Sianojentzky).
Seventh intercostal space (Beckmann; Behier).
In the left costo-xiphoid notch close to the ensiform cartilage (Laënnec, Boyer, Richerand, Müller, John B. Roberts (especially in septic cases), Allingham).

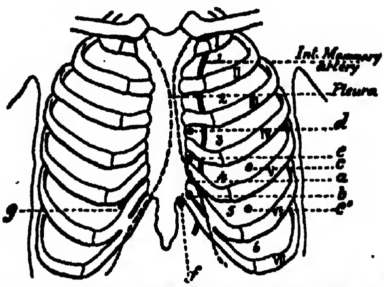

FIG. 11.—POINTS OF ELECTION IN PERICARDICENTESIS.

The dotted line shows pleura. *a*, Baizeau; *b*, Delorme and Mignon, Hare, Voinitch-Sianojentzky; *c* and *c*¹, Dieulafoy; a little to the left of these points, nearer the axillary line, would be Curschmann's preferred point; *d*, Schuh, Sharp; *e*, Trousseau; *f*, Larrey, Pendlebury, Allingham, and Roberts; *g*, Rotch, Wilson, Schapochnikoff, etc.

The technic of *paracentesis pericardii* by means of a needle or capillary trocar is perhaps best illustrated by describing the procedure as applied by Dieulafoy. As this is perhaps the most classic, best known, and probably most often applied method, Dieulafoy has his patients propped up in a semirecumbent position in bed. He selects the fourth or the fifth intercostal space, preferably the fifth, because it is nearest to the apex. The point where the needle is to enter into the thorax is marked at a distance of 6 cm. from the left border of the sternum. Needles No. 1 and 2 are used—preferably the last. After penetrating 1 cm., the aspiration is started by opening the stop-cock which leads to the vacuum already set in the syringe. The needle or trocar is gradually pushed forward obliquely from *above downward* until the liquid appears in the glass index connected with the aspirator. As the liquid diminishes in the pericardium the needle is tilted horizontally, so as to make it run parallel with the ventricle. If the needle should come in contact with the heart, the operator would be advised at once by the movements imparted to the needle by the contractions of the heart.

The simplicity of this procedure is more apparent than real, and while it will readily and safely accomplish the evacuation of the pericardium in large simple serous effusions, it is very unreliable and dangerous in all doubtful cases in which pus may exist in the pericardium, or in exploratory punctures when a simply enlarged heart has been mistaken for a pericardial effusion.

It is evident that, in the majority of procedures above referred to, the effect of puncture of the pleura has been disregarded in spite of the fact that there are recorded cases of infection of the pleura from pericardial tapping in septic cases (Delorme and Mignon, Salomoni, *et al.*). The danger is, therefore, not theoretic; and in view of the frequency with which unexpected pus or puruloid material is revealed, we would conclude that outside of strictly dropsical cases all methods which necessarily perforate the pleura should be excluded, no matter how satisfactory they may have proved to their advocates in the past.

The *danger of wounding the heart or the coronary vessels* on its surface by a puncture is not an idle fear. It has happened repeatedly, with very serious consequences (*vide infra* Accidents). This accident is undoubtedly a source of great anxiety to the operator, even though he may be a most experienced surgeon. It is interesting to note that the internists who have the least acquaintance with surgical responsibility have, with notable exceptions, championed methods of puncture and aspiration, putting off the safe aseptic open method of incision, even when the former were obviously insufficient. On the other hand, the surgeons, especially in recent years, have shown a distinct preference for the open incision, which is the only guarantee against accidental injury to the heart At any rate, the old trocar and coarse aspirating needles, and "the plunge in the dark" methods, have all been abandoned in favor of capillary puncture made with a fine needle, a little larger than is used for ordinary hypodermic medication. While it is true that the heart has been purposely punctured and aspirated for the relief of many desperate conditions (paralysis from overdistention, air embolism, etc.), it is also true that a number of instantaneous or quick deaths have unexpectedly occurred as a result of, or in connection with, injuries of the heart in pericardicentesis. In one of 80 cases reported by West two ounces of blood came through the cannula and the patient died in a few minutes; the right ventricle had been torn about the middle of its anterior aspect. In another (1868) 10½ ounces of blood came through the cannula; the left pleura was also wounded, and the patient died in two hours; more than half a pint was found in the pleura, although the heart had been repeatedly punctured without apparent bad effect. On the contrary, in a notable case reported by Sloan, this accident was followed by the most astonishingly beneficial effect. For these and other cases bearing on this point the reader is referred to Stephen Paget's admirable "Surgery of the Chest."

To guard absolutely against this most deplorable accident there is but one method, and that is open incision (with or without resection), which will expose the pericardium and allow the operator not only to feel, but to see, the heart. No form of protected or guarded trocar or cannula can prevent the penetration of the heart whenever it is bound down by adhesions to the anterior pericardial wall, or when there is a large dilatation with scant effusion; or also in cases of mistaken diagnosis, when the operator will push the instrument into the peri-

cardium and puncture the heart before he is advised by the rhythmic movements imparted by the organ to the needle that he has come in contact with the heart and that the mischief is done. J. B. Roberts says: "I and others have invented peculiar aspirating needles to avoid wounding the heart when the effusion has been nearly all evacuated; but these devices will not avert puncture of an adherent heart, or evacuate serum or pus, confined behind the heart by intrapericardial adhesions."

Even if the heart itself is not perforated, the coronary vessels, especially the vein, on account of its superficial position, may be punctured, and serious, if not fatal, hemorrhage take place (Byrom Bramwell, *et al.*). In addition to the risk of hemorrhage from injury to the heart, Delorme and Mignon found, in one of their dissections, a vein of such size lying in front of the pericardium that a free hemorrhage would have resulted from its puncture. It is greatly to the credit of the first operators who suggested relief for pericardial effusion that they anticipated the accidents reported by their successors (who used trocars and aspirators) by refusing to plunge in the dark and advising always that the open operation be performed. This they advised should be done either by trephining the sternum (Riolan, 1648; Skilderup, and later by the first successful operator, Romero, of Barcelona, 1819). Trousseau, the great exponent of the operation in France, always cut down to the pericardium, felt it, and not till then punctured it or incised it, after holding it up and away from the heart with forceps.

If open incision is the only safe and certain course, why not abandon the former and make it a rule to adopt definitely the open route to the pericardium by incision or resection? It may be answered—(1) Because adherent pericardiums with large effusions, such as would require exploration, are very exceptional; (2) because the laws regulating the disposition of the fluid accumulation in the pericardium and the means of differentiating these from heart and other lesions, by physical diagnosis and skiagraphic examination, have greatly improved the chances of a correct diagnosis; (3) because the majority of the effusions resulting from rheumatic, dropsical, and even pneumococcal pericarditis are non-purulent, aseptic, and require only simple puncture and aspiration for their relief; (4) because no deaths thus far have been recorded from capillary punctures, even when these have been known to puncture the heart; (5) because in many instances a patient will be able to stand a puncture with a needle or capillary trocar with cocain anesthesia, and will be relieved when it would be practically impossible to perform a systematic and well-planned pericardiotomy, even when a skilful surgeon, who is thoroughly familiar with the best methods of local anesthesia, is at hand; (6) the apparent simplicity of puncture in aspiration, when it is successful, and the ease with which relief is obtained in emergencies. These are the reasons, perhaps, why so many are willing to take their chances of a puncture of the heart and of the pleura with an aspirating needle, rather than transfer the case at once to the surgeon for operation. It must be admitted that,

as long as pericardial effusions are to be treated surgically only when they have attained such proportions that the entire circulatory and respiratory apparatus of the patient is crippled and the unfortunate victim is *in extremis*, the opportunity for successful surgery in this field will always be limited. Therefore, while emphatically in favor of the open method in all cases in which an aseptic, deliberate, and well-planned operation can be performed, we must admit that the exigencies of practice justify occasionally the use of the exploring needle or capillary trocar for the exploration and relief, in non-septic cases, of pericardial effusion.

Having decided that exploratory punctures are advisable, and may be even obligatory in some cases, we should adopt such precautions as will reduce the possibility of accidents to a minimum.

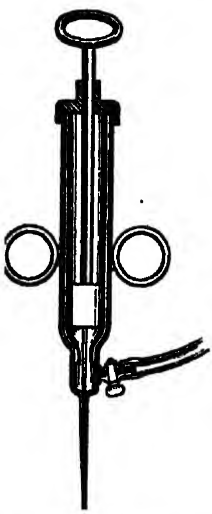

FIG. 12.—VOINITCH'S EXPLORATORY SYRINGE.

The Instruments.—An exploring syringe attached to an extra long hypodermic needle, but not over 3 cm. long, or a capillary trocar (not over half a millimeter in caliber), attached to a Potain aspirator, will do for the purpose. If the case is plainly one of hydropericardium or dropsical effusion, this puncture will serve not only for diagnostic, but for therapeutic, purposes as well. If it is a pus case or a serofibrinous case with many flocculi, the puncture will reveal: (1) The presence of the fluid; (2) its character, and (3) the depth of penetration required to reach it. It is desirable not to use *needles*, and especially needles with long points, even when they do not exceed ½ mm. in caliber; preference should always be given to capillary trocars attached to aspirators, and, for this purpose, the exploring trocar syringe (Fig. 12), devised by Voinitch-Sianojentzky, has decided advantages. In this syringe the stilet of the needle trocar is controlled by the piston head to which it is attached. The movable stilet will prevent clogging and clear the minute cannula when necessary; and the stop-cock attached to the cannula will allow the fluid to be aspirated when the syringe is full. If the fluid in the pericardium is clear, as in dropsy, this little instrument will suffice to drain the sac; if the fluid is thick (pus or blood, or any other inflammatory exudates), a sufficient quantity, if only a drop, can be brought out for diagnostic purposes.

The exploring instrument should be introduced into that part of the pericardial sac where the fluid will accumulate while the patient is in a semirecumbent position—that is, the anterior or costo-phrenic angle or cul-de-sac. To reach this cul-de-sac there are two points of election where the pericardium is pleura free—(1) the sixth left intercostal space, close to the margin of the sternum, or what we have designated as Voinitch-Sianojentzky's safety line; or (2) the left xiphoid space, in the extreme upper edge of the chondro-xiphoid angle, where

the skin may be marked with a bistoury to show the juncture of the seventh left costal cartilage and the ensiform. A needle driven obliquely upward and backward at this point, so as to avoid the diaphragm, will reach the anterior pericardial cul-de-sac, without touching the pleura or peritoneum, at a depth of ½ to 2 inches. Without denying that excellent results have been obtained by operators who have utilized many other classic or typical points of election to the left or right of the sternum, I would prefer the left xiphoid space at its extreme upper angle as the point of entrance, which offers greater advantages and less risks than any other; next to this, Voinitch's safety spot (junction of the sternum in the sixth left interspace); then, if the needle fails at these two points—Rotch's point, in the fifth *right* intercostal space, 4 cm. (1.12 inches) outside of the border of the sternum. This writer (Rotch) states that an effusion of even as little as 100 c.c. can be found at this point, and there is less danger of wounding the heart on account of the greater tendency of the fluid to accumulate on this side than on the left of the pericardium, though the pleura is bound to be perforated. Negative findings in the practice of aspiration do not necessarily exclude the presence of fluid in the pericardium.

Depth of Penetration.—To what depth should the needle penetrate through the chest in exploring the pericardium?

Terrier and Reymond state that it is prudent, unless there is a special reason to the contrary, to withdraw the needle or trocar whenever it fails to strike the fluid at a depth of 2½ cm. The vacuum should always be made slowly, as the needle is pushed forward, and the trocar or needle should never be removed suddenly. If withdrawn gradually, with the patient in the semirecumbent position, and the fluid does not appear in the syringe, it will be safer to proceed to pericardiotomy. We would insist that, after the failure of one puncture at a proper point, with a well-tested aspirating needle, it will be infinitely safer to abandon paracentesis and proceed to pericardiotomy, provided the history of the case and the physical signs confirm the necessity and urgency of pericardial exploration.

Accidents of Paracentesis.—(1) Dry puncture—*i. e.*, no fluid obtained by puncturing within safe limits of penetration—is recorded in 18 out of 180 cases (Salomoni). It is attributable to insufficient penetration; to blockade of the cannula or needle with exudates; to excessive thickening of the pericardium; to mistaken diagnosis, or to mediastinal tumors (Schuh and Rendu).

(2) Puncture and aspiration of pleural effusion mistaken for pericardial exudation (Desault, Béhier), just as the pericardium has been punctured by mistake instead of the pleura.

(3) Puncture of the heart (accidental cardiocentesis) in dilated heart or adherent pericardium. Cases of this kind are, no doubt, more numerous than are recorded. Only 2 of the patients, in a list of 11, survived the accident; the others all died either at the time of the operation or not longer than two hours after the tapping.

(4) Injury to the pleura, no doubt, occurs more often than suspected, even when efforts are made to avoid it. It occurs unavoidably in all the methods of puncture outside of the mammary vessels. In most instances it is an injury of no consequence so long as it is a capillary puncture. In pus cases, however, infection may be left in the pleural sac. In three cases pleural infections from this source have been recorded.

(5) Wounds of the lungs have occurred often, but no bad effects have been recorded.

(6) Injury to the internal mammary vessels thus far is not recorded.

(7) Sudden death without injury to the heart or other organs and from apparently no other cause than from emotional excitement in weakened patients suffering from endocardial or myocardial lesions. This occurred in 7 cases of myocardial and valvular disease.

Results.—Salomoni (1901) collected 180 cases of pericardiocentesis for pericarditis.

Serofibrinous exudate	142	94 recoveries	48 deaths
(Repeated tappings	15	10 recoveries	5 deaths)
Purulent pericarditis	21	7 recoveries	14 deaths
(Repeated tappings	5	3 recoveries	2 deaths)
Hemorrhagic pericarditis	17	5 recoveries	12 deaths
(Repeated tappings	2	1 recovery	1 death)
Total	180	106	74

When the fluid is removed, all the symptoms usually improve at once; dyspnea is relieved; edema and ascites disappear. The improvement was permanent in 99 of the 180 cases—more than half. In 22 more the puncture had to be repeated (see bracketed lines in the above table) and was followed by 14 cures—in all, 58 per cent.—but in the majority with adhesions or complete obliteration of the sac. In 74 cases (41 per cent.) death occurred speedily, by one of the accidents previously mentioned, or slowly, by persistence of the disease, septic changes in the exudates, degeneration of the myocardium, or diffusion to the pleura and lungs. From 37 to 40 per cent. of paracenteses recover (Riedinger). West, in 1883, reported from the literature 79 cases with 36 recoveries, in which the point of election for puncture was in the fifth intercostal space, one inch from the left border of the sternum. In the Schrotter-Weismayer statistics, quoted by Whittaker, 47 recovered and 53 died. In Grainger Stewart's statistics (revised by Whittaker), of 65 cases, 30 recovered absolutely, 13 were improved, and 22 died. In 2 of these cases the heart was injured and hemopericardium occurred. In all the other cases death was due to the original disease or to complications—tuberculosis, heart lesions, pleurisy, etc. Injection of irritants after pericardiocentesis was recommended by the old operators. Iodin and even carbolic acid have been injected through the cannula on the same principle that a hydrocele of the tunica vaginalis testis is treated by injection. Without attempting to discuss the obvious objections to this mode of treatment from the

modern point of view, we would state that, at the present time, the rule to drain the pericardium by open methods in all recurrent or relapsed cases, even if aseptic, would make this procedure obsolete and unnecessary.

Drainage.—After paracentesis drainage has been attempted, by introducing a tubular rubber drain through the cannula, but this practice is obsolete, being replaced by open drainage under aseptic conditions.

Pericardiotomy.—Anesthesia.—A general anesthetic is often necessary; it is indispensable in children and youths and emotional subjects. In middle life and old age the psychic element is better controlled and operations under local massive infiltration anesthesia (obtained with weak anesthetic solutions), combined with neuro-regional injections to control the intercostals, using one-tenth to two-tenths of 1 per cent. β-eucain and adrenalin chlorid solution (1 minim to every one ounce of 0.8 per cent. salt solution, as practised by myself), will probably, in many cases, obviate the necessity of administering a general anesthetic.

Methods.—As in the study of paracentesis, the practitioner will find his judgment severely taxed by the effort to make a proper selection of the numerous methods of reaching the pericardium recommended by many advocates.

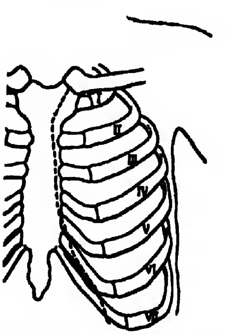

FIG. 13.—PERICARDIOTOMY IN THE SIXTH LEFT INTERSPACE (THE HEAVY BLACK LINE) WITHOUT COSTAL RESECTION (Desault). (Terrier and Reymond.)

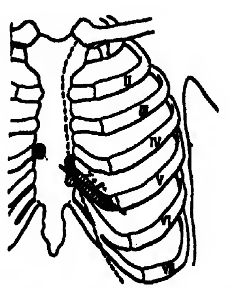

FIG. 14.—PERICARDIOTOMY. Resection of the left fifth costal cartilage (Ollier's method). (Terrier and Reymond.)

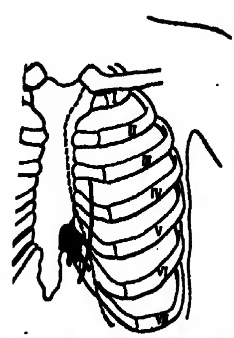

FIG. 15.—PERICARDIOTOMY FOR SMALL ACCUMULATIONS. (Terrier and Reymond.)

Vertical incision 6 cm. long over the sixth left sternochondral joint. Resection of the sixth and seventh costal cartilages, including adjoining edge of sternum (Voinitch).

Pericardiotomy with Resection.—(*a*) Subperiosteal resection of the fifth left costal cartilage (Fig. 14) is recommended by Ollier (1891), Brentano, Koerte, and subsequently by C. B. Porter (1897–1900) and by (*b*) Durand, who modifies the operation by excising the adjacent part of the sternum when more space is required. (*c*) Resection of the fifth and sixth left costal cartilage by vertical incision (Delorme and Mignon); (*d*) resection of the fourth left cartilage by von Eiselsberg; (*e*) chondroplastic flap, including portions of the fifth and sixth costal cartilage, which is turned upward like a trap-door reflected, as on a hinge, over

the soft tissues in the third intercostal space; (*f*) Voinitch-Sianojentzky, who has made a particularly detailed study of pericardiotomy, advocates *three* procedures (Figs. 13–15), in accordance with the quantity of fluid estimated to be in the pericardium.

The objection to all this is that it is often difficult to make a diagnosis of effusion at all, much less attempt to estimate the probable quantity contained in the sac before operation. The anterior area of dulness is not a reliable guide of the amount that may be lodged behind the heart in the posterior areas. It is interesting to notice, however, that Voinitch has adopted, as the safest point for resection, in dealing with only suspected or very small effusions, a small area involving the sixth and seventh cartilage, with the lower left angle of the sternum, and in this way giving his support as a most competent anatomist to the *present tendency, which is to attack the pericardium through the extreme lower end of the sternum and the ensiform cartilage.*

It is also interesting to notice that the experience of many operators of a recent period confirms the view that the interpleural space widens in proportion to the amount of the exudation. This is the only way we can account, unless it be by the obliteration of the pleural sac, for the immunity from pneumothorax which has been enjoyed by West (1883) and his followers, who were able to enter the pericardium by an incision in the fifth interspace below the nipple; and by Koerte (1892), who drained on a level with the upper part of the fifth interspace, beyond the line of the chondral junction. The practice of other operators, who incise the pericardium systematically below the left nipple-line, would also support this belief.

After considering these various methods consistently with the reasons which led me to select the immediate left lower sternal and parasternal region as the safest and best for paracentesis, I must again express my preference for this route for pericardiotomy, just as we must aim in puncturing the pericardium to select that spot which will avoid the blood-vessels and the pleura and yet strike the pericardial accumulation where it is largest and most dependent, and where, in addition, the lower sternophrenic reflection of the pericardium will insure the greatest protection to the heart.

The anatomic mind of Riolan (1848) foresaw the advantages of this route and advised trephining the sternum. Mallé (1855) was the first to operate by the sternal route. Skilderup proposed trephining the sternum below the line of the fifth costal cartilage. (Laënnec advised that the opening be extended to the ensiform cartilage; Bekmann, 1891, of Warsaw, was the first to obtain a complete success by this method). A number of theoretic objections have been made to the sternal route by those who fear that it endangers the pleura and that it gives insufficient space or who look upon it as a complicated operation, while the surgeons who have adopted the sternal route appear to be perfectly satisfied with it. Durand, Voinitch, and J. B. Roberts all agree that it is the safest and easiest route from the anatomic point of view, and it is only because of apparent lack of space that they seem to have adopted other para-

sternal procedures. It is interesting to note that this, the oldest of methods, has been resurrected and made the most available at the present time by the improvements of modern technic. Pendlebury has called attention to the excellence of the method, which was first described by Drs. Ogle and Herbert Allingham in 1900, and performed by the last-mentioned operator subsequently, with repeated success. Pendlebury, who slightly modified the Allingham operation (Fig. 16), is convinced, by his experience, that this procedure, with such slight modifications as may be necessary in individual cases, must become the routine method for drainage of the pericardium. "It can be claimed that the operation is simple and of short duration, and that it affords excellent drainage from the lowest available spot of the pericardial cavity." A vertical incision, 4½ inches long, is made, with its center at the lower border of the seventh costal cartilage, parallel with and one inch from the left border of the sternum. The skin and fascia are reflected

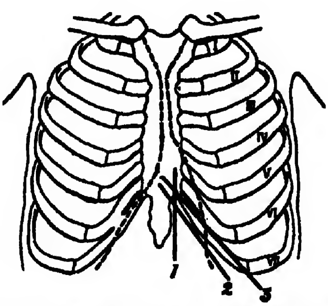

FIG. 16.—PERICARDIOTOMY. (Terrier and Reymond.)

1, Vertical incision to open the pleura-free pericardial space—Allingham-Pendlebury incision; 2, oblique costoxiphoid incision, without resection, suggested by Larrey; 3, oblique incision with resection (subperiosteal) of the left seventh chondral cartilage—Mintz incision.

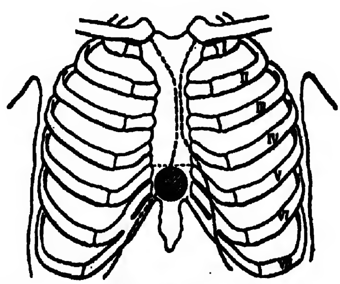

FIG. 17.—PERICARDIOTOMY. (Adapted from Terrier and Reymond.)

The sternal route by trephining of the sternum—Rision-Skielderup procedure; again recommended in 1906 by Bacon, of Cleveland.

inward and outward, and the abdominal muscles (rectus and oblique) are detached from the seventh costal cartilage. The cellular interval, "costo-xiphoid space," containing the superior epigastric artery, is broken into with the fingers, some of the fibers of the diaphragm being torn. If the pericardium is distended, it will now come to view, or at least can be felt. If more space is required to explore the pericardial sac itself, by introducing the finger 2 inches of the seventh left costal cartilage can now readily be excised by rongeur forceps. The internal mammary vessels are now exposed and held aside or tied. More loose connective tissue, fat, and the triangularis sterni will have to be put aside. Then the pericardium, tense and thick, is exposed. If necessary, the cartilage at the sixth rib may also be readily removed. But this should not be necessary for simple exploration and drainage. In children it is not necessary to excise the cartilage of the seventh rib. The operation has been performed three times by Pendlebury and

Allingham. It is well to bear in mind not to incise the pericardium until after carefully pushing aside the right and left pleuræ. In order to avoid opening the peritoneum, the pericardium should be opened just above the level of the base of the ensiform cartilage, and, with the finger, the opening should be enlarged downward into the costo-xiphoid space. A soft-rubber tube should be left for two or three days.

Mintz elaborated the following technic: An incision 7 cm. in length is made along the border of the seventh costal cartilage (Fig. 16); the abdominal muscles are separated from the under surfaces of this rib, a section of which is removed. The internal mammary artery crosses the wound and should be ligated. With one finger the operator compresses the diaphragm and exposes to view the angle of the pleura, and also, somewhat higher and toward the median line, the pericardial sac. If the latter is opened at this point, one is assured of thorough drainage, inasmuch as the opening is made in the most dependent position. As Mintz states, this method of approach was suggested almost a century ago by Larrey; like the old operation, the only serious objection to it is the necessary division of the recti and abdominal muscles, which is obviated by the straight incision of the previous operators. Finally, J. H. Bacon, of Cleveland, Ohio, as a pathologist, has been impressed with the great frequency of pericarditis as a complication of other diseases, and the comparative ease with which the pericardium may be explored through an opening in the sternum. He has found but a single case in 110 autopsies, in which he would have failed to enter the pericardium by going through the sternum on a level with the fifth costal cartilage, and this was in a child of eight years with a pigeon-shaped breast.

In children the sternum is narrow, and one may make the incision nearer the mid-line, so that the trephine opening may not separate a rib from the sternum. The sternum averages $\frac{3}{4}$ cm. in thickness in the adult, but varies considerably. If necessary, the opening may be enlarged in any direction, according to the indication, especially if Voinitch's, Porter's, and von Eiselsberg's suggestion is to be carried out, viz., to suture the lips of the pericardial wound to the skin in order to avoid septic mediastinitis. This is preferable and more reliable than filling the cellular portion of the cut edge of the bone with a 15 per cent. iodoform wax, to guard against infecting the bone, etc.

Post-operative Treatment.—Position of the Patient.—The anatomic study of the pericardium and the experimental observation made by all recent observers point to the right antero-inferior angle of the pericardium as the most dependent portion of the sac when the patient is sitting up in a semirecumbent position. We should, therefore, advise that all patients who have been drained by the sternal or parasternal routes, previously described, should be propped up in bed still higher than in the semirecumbent position, and not kept flat on their backs for fear of retaining secretions.

Drainage.—Drainage after pericardiotomy is to be governed by the same rules that guide the surgeon in the post-operative management

of empyema and pleural infections. One or two soft tubes introduced into the lower right angle of the pericardium will not only favor drainage, but facilitate irrigation if this becomes necessary. In saprophytic and the more active pyogenic infections (staphylococcal and streptococcal), where absolute drainage must be maintained, in addition to facilities for irrigation, a double tubular drain would be preferable; in the simple serofibrinous and non-virulent pneumococcal infections a simple gauze drain wrapped in a rubber strip (cigarette drain) would answer the purpose. Voinitch is in favor of the gauze drain, and Serafini and Levy, in their recent contribution, conclude that gauze (cigarette) drains are better tolerated. Clinical experience, however, shows distinctly that some of the best results have been obtained by tubular drainage. That the mode of drainage must be selected according to the virulence of the exudate is, we believe, the rule best adapted to the varying conditions met in practice. In irrigating the pericardium, plain sterile physiologic salt solution should be used; death has followed irrigation with strong antiseptic fluids.

Results.—The statistics of pericardiotomy, as well as pericardicentesis, are absolutely unreliable as guides to the prognosis. On the one hand, the mere excision of a fragment of the sternum and of the ensiform cartilage would scarcely add to the gravity of the simple pericardiotomy or the incision. On the other hand, a simple incision, made in an intercostal space, would become a very grave operation if it opened the pleura, creating an acute pneumothorax and subsequently complicating the pericarditis with an acute septic pleurisy.

Reichard further illustrates the fallacy of statistics. He collected 33 cases, in 19 of which incision was practised alone, and in 14 with the resection of the cartilage. Of the 19 cases, 6 recovered and 13 died; of the 14 resections, 8 recovered and 6 died. On this statement of figures he concludes that the safest procedure is resection. Le Conte, who analyzes these statistics carefully, shows plainly enough that the conclusion is not justified by the facts, and that, in reality, the statistics of the two procedures may be regarded as very nearly equal in the same class of cases.

In looking at the mortality associated with pericardiotomy as a whole, and simply with the view of determining the fate of the patients whose conditions demand this operation, irrespective of causes, we find that in 36 cases collected in 1901 by Salomoni, 20 recovered and 16 died, and in several of the cases that died the operation was purely of a palliative character for incurable septic, scorbutic, and tuberculous conditions.

In 1900, C. B. Porter, of Boston, reported 51 cases of suppurative pericarditis treated by operation, including J. B. Robert's 35 cases and others published up to that time. The most frequent single cause was pneumonia (14 cases). Of the total 51 cases of pericardiotomy, 20 recovered and 31 died, a mortality for all cases of 60.5 per cent.

E. Elliott, Jr. (1909), has added 22 cases which have been recorded in the literature since Porter's publication. Seven deaths occurred in this latest group, or 31.8 per cent. mortality. Such a showing is very satisfactory when it is known that, without operation, practically all cases die, and that, with repeated aspirations, nearly every case reported has terminated fatally.

Adhesive or Plastic Pericarditis; Cardiosymphysis; Cardiolysis. —Adhesive or plastic pericarditis presents itself in two well-known varieties, due respectively to inflammation of the inner or serous layer of the pericardium (pericarditis interna), or to the combined inflammation of the internal and external layers (pericarditis externa). These two types must be kept distinctly apart, because simple internal (serous) plastic pericarditis with the formation of pericardial bands in isolated patches is a very frequent, if not constant, sequel of all forms of suppurative pericarditis in many serofibrinous types of the disease. Adhesions from this cause and in isolated patches are found in about 5 per cent. of all autopsies (Chambers, Leudet Geist), whereas total or extensive adhesions are found only in about 2½ per cent., Leudet; Willigh, 1½ per cent.; Reisman found pericarditis in 7.7 per cent. of autopsies in the Philadelphia Hospital, and of these, 20 per cent. were adhesive. The second variety of pericarditis involving the entire thickness of the membrane leads to complete obliteration of the pericardial sac more often than the first variety. This is often associated with a chronic hyperplastic mediastinitis which, whether beginning in the pericardium itself or elsewhere, continues to involve all the connective tissues in the mediastinal spaces. By the persistence of this process the pleura, pericardium, and mediastinal connective tissue are all fused or amalgamated into a dense, indurated fibrous tissue which, by extending downward along the diaphragm and the peritoneum, finally involves the liver, causing a cirrhosis. On the other hand, the myocardium and the heart-valves are apt to be implicated in the extension of the fibrosis inward, causing secondary degenerative changes in that organ, which soon tell on the general circulation and lead to a fatal termination. *Concretio pericardii*, or calcification of the pericardium, appears frequently as a phase of the same general fibroid process, generally recognized as mediastino-pericarditis.

When the bands of adhesions are long, filamentous, and limited to small areas (partial synechiæ), they scarcely interfere with the heart's action, and remain latent throughout life. On the other hand, when the adhesions are broad and dense and finally obliterate the pericardial cavity, they cause hypertrophy and dilatation and finally atrophic and degenerative changes, which lead to a clinical picture that is characteristic and invariably fatal.

When complete cardiac symphysis (*i. e.*, obliteration of the pericardial sac by adhesion) exists, it may be recognized in the more characteristic cases by the following group of signs: Systolic retraction of the intercostal spaces at the apex-beat (sign of Hein-Kreysig), rhythmic undulations of the thoracic walls (Sanders' sign),

the rolling movement of the precordia (*movement de roulis*, or Jaccoud's sign); fixed limit of the left border of cardiac dulness, indicating adhesion of the pericardium to the pleura (C. J. B. Williams' sign), diastolic shock at apex, and diastolic collapse of the cervical veins (Friedrich's sign); rhythmic retraction in the neighborhood of the eleventh and twelfth ribs, posteriorly, on the left side, caused by traction on the diaphragm (Broadbent's sign); *pulsus paradoxus*, a small, feeble pulse-wave during inspiration (Kussmaul's sign); fixed and immovable position of the axis of the heart in the respiratory movements.

In connection with these physical signs all the clinical symptoms of exhaustion of the myocardium and cardiac insufficiency develop; pain, anxiety, precordial distress, edema of the extremities, ascites, enlarged liver, pulmonary stasis, edema of the lungs, dyspnea, cyanosis, arhythmia, and death from cardiac exhaustion. In children, when pericardial adhesions exist to the extent of producing a complete symphysis, a group of symptoms develops which have been recently described by an almost pathognomonic syndrome by Flesch and Schlossberger, of Bokay's clinic, in Budapest, *i. e.*, ascites with increased size of the liver; puffiness of face; cyanosis of face and lobules of ears; very slight diminution in pulse-rate, and almost normal auscultatory condition of the heart—this they regard as an almost certain sign of the most frequent type of adhesive pericarditis in children.

Treatment.—The only hope for patients of this kind lies in surgery. Delorme proposed to open the pericardium and break up the adhesions with the fingers or blunt scissors in order to liberate the organ when these were not universal or too dense. As these cases are not recognized until the secondary degenerative changes of the heart have taken place, it is evident that a pericardiotomy under these conditions would scarcely be tolerated without consequences; furthermore, the adhesions would necessarily be reproduced by the traumatism. A far better suggestion, at least, a safer one, is that offered by Brauer, of Marburg, under the name of cardiolysis. Reasoning on the basis that the systolic retraction of the chest-wall, by adhesions to the pericardium and heart, is obtained at the expense of extra work imposed upon the cardiac muscles, and since it is impossible to obtain a true cardiolysis (or, better, cardioschesis) by breaking up the adhesions, Brauer suggests that functional relief can be given the heart by removing the overlying and resisting osteocartilaginous wall in front of the pericardium. This object is to be obtained by excising the ribs and the periosteum from the sternal attachments of the cartilages to the anterior mammillary or axillary line. This transforms the rigid precordial region into a soft, yielding wall, which follows the movements of the heart without resistance. Brauer's operation was performed by Petersen and Simon, of Heidelberg, the results corresponding to the expectations. Marked improvement was observed in all 3 patients operated upon, 2 recovering and 1 dying, finally, from bronchopneumonia. The edema, dyspnea, cyanosis, ascites, which existed in all 3 cases, subsided after the operation. Petersen recommends that three ribs be removed to begin with,

the necessity of removing a portion of the sternum as well being subsequently determined by the condition of the patient. A subperiosteal resection will do (Koenig, Blauel), but the removal of the anterior periosteal layer is preferable to prevent osseous regeneration. Although the operation in all 3 cases was performed to relieve adhesions caused by chronic mediastino-pericarditis, the same principle suggests itself as a valuable means of preventing the evil effects of the unavoidable adhesions which will follow in septic cases of cardiac traumatism or after prolonged drainage of the pericardium. Therefore, in making osteoplastic flaps to gain access to the heart, when this is wounded, or in any other circumstances, the operator need not be so particular about the preservation of the osseous framework of the flap, but may with perfect propriety deem it his duty to remove all the bones as a simple prophylactic measure.

Wounds of the Pericardium.—At one time it was believed that a wound of the pericardium without a simultaneous injury to the heart was almost impossible, and if it did happen in very exceptional instances, a fatal termination was inevitable. At the present time, with a large and accumulating experience in cardiac and pericardiac surgery, we have come to realize that the separate injury of the pericardium occurs with relative frequency, and that intrinsically the prognosis of such wounds is not worse than those of any other serous cavity, except for the complications that occur at the time and subsequent to the injury. Although the total number of recorded wounds of the pericardium exclusive of the heart is comparatively small, the literature shows, nevertheless, that any part of the serous sac may be involved—the anterior more often than the lateral surfaces, the posterior than the upper portion of the sac—the latter most fatal because the vascular trunks are most exposed to injury—and at the base, where the diaphragm may be perforated from above or from below through the abdomen.

The dimensions and form of the pericardial wound correspond, in general, to the external wound. Sometimes the wounds appear smaller than they really are, and may escape observation unless the examinations are carefully made. In subcutaneous injuries the wound may be punctiform, caused by a sharp fragment or spicule of bone. "In all cases of rupture of the pericardium without lesion of the heart—in crushed and contused wounds of the chest—the rent has been of large size and has been accompanied by fractures of the ribs and sternum" (Follin). Bennett records a notable exception to the rule. A painter, aged twenty-two, fell on his shoulder and head, a distance of 30 feet; he died in less than two hours. The pericardial tear found at the autopsy was large enough to admit the hand, and yet the heart was bruised only superficially and not ruptured. The chest-wall was uninjured. G. Fischer collected 51 cases of injury of the pericardium from the literature, with 22 recoveries. The statistics of Loison show a proportion of 66 per cent. of pericardial injuries without cardiac involvement in cases of pin or needle injuries; 11.1 per cent. in stab wounds; 12.2 per cent. in

gunshot wounds. In a study of thoracic wounds which were treated in his clinic, Borszcky noted that out of 42 penetrating stab wounds of the thorax, there was 1 cardiac and 1 pericardiac injury. In 89 gunshot wounds of the thorax, he observed 1 of the pericardium and 2 of the heart. In a study of gunshot wounds of the pericardium Eichel compiled 27 cases, of which 8 were uncomplicated pericardial wounds in which the isolated injury of the pericardium was confirmed 4 times by the autopsy and 4 times at the operation. Of the 4 cases operated upon, 3 made a perfect recovery. In 4 cases operated upon by Riedel, Koerte, Seydel, and Eichel, the pericardium alone, and not the heart, was found injured.

"Percutaneous injuries of the pericardium, without wound of the heart, are represented in the literature by a few isolated cases. When only a slight hemorrhage occurs after an injury of this kind, the natural tendency is to assume that the heart has escaped. On the other hand, it may happen that there is a severe hemorrhage, demanding the enlargement of the wound and exposure of the heart, and that then no cardiac wound is discovered. The wound may, however, exist, escaping detection on account of its minute size. In a case described by Tassi, the bloody extravasation in the pericardium, which was dangerous enough to justify surgical interference, originated from a divided artery in the pericardium" (Weinlechner). Acting on the rule that, in the presence of a severe hemorrhage filling the pericardium, pericardiotomy is indicated, the same author reports a case of injury of this kind without associated cardiac injury, in which he drained, with recovery.

Foreign Bodies in the Pericardium.—The presence of foreign bodies in the wound complicated one out of every five cases of pericardial injury, according to Salomoni. Of these foreign bodies, the greater number are bullets, needles that had been swallowed per os, artificial dentures which had found their way into the pericardium by the esophageal route. In bullet injuries the missiles are usually found free or encysted in the sac; they either drop in the sac or fall into the pericardium, after injuring the heart, as a result of muscular contraction. While the presence of these bullets may give rise to a complex group of symptoms and signs, it may happen that a bullet will remain inert in a pericardial sac as long as fifty-two years without causing disturbances. Such is the case of the wounded soldier of Salamanca, quoted by Picqué, who was shot in 1812 and died in 1864. At the autopsy a ball was found encysted in the pericardium. Other cases of the same kind are reported by Malecot, MacDowell, Rokitansky, and other pathologists. Several bullets recovered from the pericardium and the heart-wall itself, by direct operative intervention, are reckoned among the most brilliant surgical triumphs of the last decade.

Suppurative pericarditis follows wounds inflicted with soiled weapons and infected foreign bodies. Many cases are on record, however, in which healing has followed without infection. Very often, though not constantly, plastic pericarditis will follow even aseptic wounds, without, however, as a rule, developing a complete symphysis.

Fully 30 per cent. of all pericardial wounds recovered in the pre-antiseptic days. At present the mortality of uncomplicated pericardial wounds (very rare) should be very much less, in view of the greater care now taken to prevent infection. The outlook for recovery in every case must depend upon the associated complications, which almost invariably exist (apart from heart injuries, which we will consider separately), and also contribute to the gravity of these cases.

Treatment.—See Injuries of the Heart.

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SURGERY OF THE HEART.

History.—"The road to the heart is only 2 or 3 cm. in length in a direct line, but it has taken surgery nearly 2400 years to travel it" (Harry Sherman). The record of this long journey may be conveniently divided into four periods:

First period: From Hippocrates and the ancients to Ambroise Paré (1509–1590). This is the mystic and legendary period. Wounds of the heart were then regarded as absolutely and necessarily fatal. No treatment was attempted.

Second period: From Paré to George Fischer (1868). Wounds of the heart are no longer regarded as necessarily fatal. The causes of death are investigated. The pathologic anatomy and physiology of these wounds are studied. Some experimental work is done, and some treatment is attempted. This period culminates with the monumental monograph of Fischer, which summarizes all the knowledge obtainable up to that time, and exercises a more powerful influence than any other agency in preparing the surgical mind for the possibilities of cardiac surgery.

Third period: From George Fischer to Farina (1896). This is the beginning of the experimental period, in which the tolerance of the heart to surgical manipulations and trauma is demonstrated by the experiments of Rosenthal, Bloch, Salomoni, Del Vecchio, Bonomi, and Martinotti (1888), Bode (1897), Elsberg (1898), *et al.* This period is merely a preparatory and short prelude to the great clinical epoch that follows.

Fourth period: This is the surgical period, beginning with Farina's first case of cardiorrhaphy in 1896, and continuing uninterruptedly and progressively to the present time. The road opened by Farina, Capellan, and Rehn (1896) is rapidly followed by a host of other operators, whose labors, up to January 1, 1907, swelled the list of the reported operations on the heart itself to 160 cases with 62 recoveries, a mortality of 43.83 per cent. (Salomoni). The heart has now become a surgical organ, and is subjected to the same laws and technical procedures which govern the interventions of surgery in the treatment of the injuries and traumatisms of all the hollow viscera. At the end of a decade of operative experience in cardiac surgery sufficient material has accumulated to permit of the systematic study of the surgical lesions of this organ as seen in life—on the operating table, and not, as in the past, exclusively in the dead-house or in the experimental laboratory. The decade closes with one of the most legitimate and brilliant conquests of conservative surgery.

The Surgical Topography of the Heart.—The heart lies in the middle mediastinal space, between the lungs. Its entire anterior surface is closely related to the anterior walls of the thorax. Together with the large vessels, it is well protected by the manubrium and body of the sternum, as well as by the cartilages of the ribs from the third to the sixth, on the left side, and by a very small part of the third and fourth costal cartilages on the right. It is, therefore, proper, from the topographic point of view, to refer to the sternal and chondro-costal portions of the heart (Jamain). The sternum covers more than two-thirds of the right ventricle, right auricle, and a part of the left atrium auriculi, over which lie the aorta and pulmonary artery. The chondro-sternal portion of the heart corresponds to the tip of the right ventricle, almost the entire left ventricle and left auricle. The topographic relations between the heart and the pericardium and of the internal mammary arteries, of great importance in connection with heart wounds, have been sufficiently outlined in the description of the pericardium. While the outline of the heart, as mapped out by topographic anatomists,

is quite variable, the differences between these descriptions are not of great importance from the practical point of view. Holden's classic landmarks, which are in accord with the majority of anatomists, will answer the purpose of the clinician and surgeon quite satisfactorily.

Rules.—(*a*) To define the *base*, draw a transverse line across the sternum, corresponding with the upper border of the third costal cartilage; continue the line one-half inch to the right of the sternum and one inch to the left. (*b*) To find the *apex*, mark a point about two inches below the left nipple (male) and one inch to its sternal side. This point will usually be found between the fifth and sixth ribs, three and one-half inches from the middle line of the sternum. (*c*) The *lower border*, which lies on the central tendon of the diaphragm, is indicated by a line slightly curved downward, from the apex across the bottom of the sternum (sterno-xiphoid junction) as far as its right edge. (*d*) The *right border* (formed by the right auricle) is outlined by continuing the last point upward from the right sterno-xiphoid junction with an outward curve, so as to join the right end of the base. (*e*) To define the *left border* (formed by the left ventricle), draw a line curving to the left, not including the nipple, from the left end of the base line to the apex.

The greater part of the heart lies within the left half of the chest; the only part which lies on the right of the sternum is the right auricle.

The anterior auriculoventricular groove, in which lies the left coronary artery, is indicated by a line (with convexity upward) extending from the right heart border to the left, crossing the midline of the sternum on a level with the lower border of the third cartilage. While, as a rule, the heart is wounded on its anterior surface, it must not be overlooked that it is not infrequently injured by weapons, missiles, etc., that penetrate posteriorly close to the vertebral column. The auricles, especially the left, are nearest the bodies of the vertebræ, and can be easily reached by a penetrating stab or puncture anywhere between the fourth dorsal vertebra and the spinous process of the eighth. These are the "cardiac vertebræ" of C. Giacomini. The heart is likewise exposed to injury by attacks on the lateral aspects of the thorax, and by wounds which penetrate the abdominal walls upward and through the subphrenic space.

Experimental Data and Physiopathology of the Wounded Heart.—The systematic and surgical study of cardiac wounds in the lower animals did not begin until 1882, with the publication of the researches of Bloch, of Copenhagen. Bloch confirmed Morgagni's early observations that cardiac wounds were well tolerated and that, when death took place, it occurred not only by the depletion of the vascular system, directly through the wounds which opened the heart chambers, but more often, as Morgagni had shown, by the compressive action of the blood on the heart as it was poured into the closed pericardial sac. As a result of his experiments, Bloch boldly proposed the suture of heart wounds as a surgical remedy, and successfully demonstrated its feasibility on the lower animals for the first time. Del Vecchio (1894), Salomoni (1896), Rehn (1897 and 1906), Bode (1898), Elsberg (1898), Wehr (1900), Sherman (1902), Villar (1902), Spangaro (1906–07), Gobell (1907), Sauerbruch, Von Hackel (1907–08), and others not only

confirmed the early experiments showing the tolerance of the heart to traumatism and surgical manipulations, but contributed to the improvement of the technic of suture on the human subject, which was steadily gaining ground in the mean time. They also proved that the suture of heart wounds insures a much better and safer healing than when these are allowed to heal spontaneously. Spangaro, of Padua, has recently analyzed the experimental evidence on this subject most thoroughly. Among other conclusions which will be referred to in dealing with the technic of heart suture, Spangaro summarizes the data obtained by experimentation as follows:

(1) That the heart, though quite tolerant of manipulations and traumatic insults of various kinds, is sensitive to injury, the evil effect of which is soon manifested by the general circulation.

(2) In all cardiac injuries there are three chief elements to be considered: (*a*) The effect of the mere stimulation by contact or mechanical irritation, etc., on the cardiac muscle. (*b*) The effect of procedures or manipulations which merely obstruct the heart and prevent the filling and emptying of the heart chambers, and thus interfere with the coronary, the intracardiac, and the general circulation. (*c*) The effects of traumatisms which penetrate the heart-chambers, tap these cavities, and thus lower the blood tension by draining the total mass of the circulating blood, leading to acute traumatic anemia.

(3) Any direct mechanical stimulation of short duration applied to the heart will invariably bring about a momentary arrest of the heart, which is quickly followed by a systolic contraction of compensatory intensity. If the stimulation is continued, the pulse is retarded, irregular systolic contractions, arhythmia, and a slight fall in the blood-pressure are obtained.

(4) All parts of the heart respond invariably and in the same characteristic manner to mechanical irritation. The exhausting effect of the permanent irritation upon the heart will become more marked with the duration and intensity of the irritation.

(5) Mechanical obstructions to the circulation of the blood in the cardiac chambers diminish the excursions of the heart muscle and its range of motion, create disorder in the cardiac cycle and peripheral pulse, and are followed by a general and rapid fall of the blood-pressure. Examples: Traction on the pericardium so as to displace the heart forward toward the wound; compression of the heart by grasping it in the hand; traction on the heart by pulling it sufficiently to elongate it; compressing the heart against the edge of the wound in the chest-wall; pulling on it so as to dislocate it out of the thorax, and lifting it up so as to make traction on the great vessels at the root of the heart, as in attempting to inspect the posterior surface; twisting it on its axis; compression of either one or both venæ cavæ at the atria, or of the auricles. All these manipulations, so often called for in the emergencies of cardiorrhaphy, act injuriously on the general circulation and lower the general blood-pressure proportionally to the duration and completeness of the cardiac obstruction thus produced.

(6) The loss of blood caused by penetrating wounds of the heart diminishes the general arterial pressure proportionally to the rapidity and volume of the flow, and acts most injuriously by annuling the effect of the secondary compensatory systolic contraction in the effort to fill up the vascular tree. If the wound is large, death follows quickly from acute anemia of the brain and nerve-centers.

(7) When progressive hemorrhage occurs into a closed pericardium (hemopericardium), a gradual interference with the heart action follows, proportional to the increase in the intrapericardial pressure. The diastolic dilatation of the auricles and ventricles is interfered with, and the inflow of blood into the auricles and ventricles is prevented. The heart is thus strangulated, as it were, at its base. This is followed by a progressive fall in the general arterial blood-pressure, a rise in the venous tension, and increasing rapidity, as well as emptiness of the peripheral pulse. This "heart compression" (Rehn), first described by Morgagni and subsequently insisted upon by E. Rose (1884), as "Herz-Tamponade," is the most frequent cause of death in heart injuries, and furnishes the clearest and most imperative indications for operative interference.

François Franck, by experiments on dogs, determined that the auricles are compressed as soon as the pressure on the pericardium exceeds the pressure in the large veins. Lagrolet, who confirmed this observation, also demonstrated that an animal with a cardiac wound dies more promptly when the pericardium is closed than when it is open and the blood is allowed to escape. There is no doubt that rapidly increasing heart pressure may kill very quickly, even before the pericardium has become much distended. In some cases 250 c.c. of blood pent up in the pericardium have proved sufficient (Rehn). On the other hand, if the wound is small and superficial and the heart pressure is slowly developed, it may prove in itself to have a salutary and life-saving effect by arresting the hemorrhage. A number of these cases owe their recovery, no doubt, to this factor. It is wrong, however, to count upon such a fortunate event. Another hemorrhage follows as the hemostatic thrombus is washed away by the increasing vigor of the circulation, and the patient dies from heart-compression—unless relieved by art.

(8) When intrapericardiac tension is relieved by tapping the pericardium and draining the pent-up blood, the arterial pressure rises instantly, the frequency of the pulse is diminished, cyanosis and venous turgescence disappear, and the rhythm of the heart is restored.

(9) By suturing a penetrating heart wound, which has caused exsanguination to the extent of extinguishing the carotid pulse, the blood-pressure and the peripheral pulse may be gradually restored; especially if artificial respiration is kept up.

The Control of the Cardiac Circulation.—*Prophylactic Surgical Hemostasis by Digital Compression.*—In connection with the practicability of controlling arterial hemorrhage from the heart during the performance of suture Rehn (1907) reported several experiments performed by himself and others, which support his belief that temporary ischemia of the heart can be absolutely obtained by com-

pressing the right venous atrium, *i. e.*, the venæ cavæ at their entrance into the right auricle of the heart. In this way no blood could enter the heart, and the circulation would be entirely arrested while the compression lasted. However, the experimental evidence and also some of the clinical observations (Villar, Guinard) would seem to show that this procedure can be kept up for a few seconds—just long enough to allow the suture of a heart wound—sufficiently long to arrest a hemorrhage which, if continued, will quickly extinguish life. Gottlieb repeated Rehn's experiments and confirmed his conclusions:

(1) That hemorrhage from any wound of the heart may be arrested by compression of the right auricle, or at least controlled by a *partial* compression sufficiently to permit the bloodless suture of the heart (Figs. 18 and 19).

(2) Partial compression is practically tolerated by the dog's heart up to four minutes, probably even longer; total compression, positively up to one to one and one-half minutes; beyond that time, uncertain. Beyond a doubt, the human heart will prove far more tolerant of this procedure. In the dog the especial danger is in "fibrillation" or irregular insufficient myocardial contraction, which is irremediable in the dog, and is only transitory in the rabbit and cat.

FIG. 18.—COMPRESSION OF RIGHT HEART. FIRST STEP (Sauerbruch).

The right auricle at the entrance of the great veins placed between the third and fourth fingers.

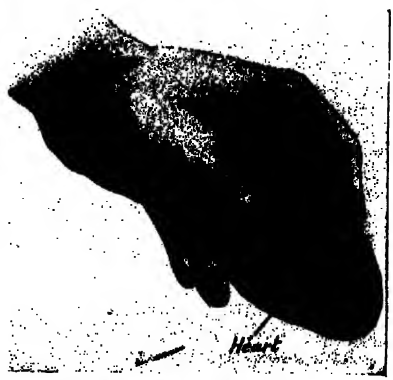

FIG. 19.—COMPRESSION OF RIGHT HEART. SECOND STEP (Sauerbruch).

Heart held ready for suture by the thumb and index-finger.

By compressing the superior and inferior venæ cavæ with soft clamps, Sauerbruch and Von Hacker, working on dogs in Sauerbruch's chamber, found that almost complete ischemia of the heart could be obtained for ten minutes without fatal consequences. After ligature of the cavæ alone, dogs die in four to twelve hours, with progressive lowering of the blood-pressure.

Laewen and Siewers (1908), in a research to determine the effect upon the circulation and degree of tolerance of provisional ligation of the pulmonary artery and the aorta, while extracting thrombi and emboli from the pulmonary artery (Trendelenburg's operation), found that in rabbits the heart could be made to resume its functions after six minutes of continuous compression of these two arteries. The brain showed much less resistance than the heart to the effects

of the ischemia brought about by this procedure. It was found that beyond one minute of time it was unsafe to continue the joint compression of the pulmonary artery and the aorta. To obviate the dangers of permanent and irremediable damage to the brain, the compression of the aorta at least should be interrupted once a minute. These observers also noted that while compression of the right auricle or of the venæ cavæ separately, as proposed by Rehn and Sauerbruch, is well tolerated by the heart for as long as ten minutes, the brain was permanently damaged after nine minutes' compression. Three and three-quarter minutes is the maximum time limit of ischemia that the brain and the heart will tolerate in rabbits with any degree of safety.

Preservation of the Contractility of the Heart Muscle after Exclusion of the Circulation.—According to Tigerstaedt, the heart is not nearly so dependent upon its blood-supply as was formerly assumed. The circulation in the rabbit's heart may be suspended during six minutes, and yet the organ will recover. According to the same observer, it is possible for a heart which has been excluded from the circulation for ten minutes and over to be brought to life again by blood transfusion. The length of time that the contractility of the heart is preserved after death or after detachment from the body—as recorded by recent experimental research—is marvelous. The excised heart of a rabbit, which had been kept hanging in the laboratory for *five* days, was transfused with Locke's solution and made to contract sufficiently to give tracings 2.5 mm. high (Lock and Rosenheim, 1905).

Kuliabko (1902) established an artificial circulation in a rabbit's heart which had been removed from the body. It was kept at a temperature of 40° C. and showed regular contractions. After a half-hour it was placed in an ice-chest for eighteen hours, when the experiment was repeated, and after less than half a minute the heart recovered its rhythmic contractions, these beginning at the openings of the venæ cavæ. The movements then extended to the right ventricle, but not to the left; in four and one-half hours the pulsations ceased. Kuliabko also took the heart of an infant three months old who had died of double pneumonia. *Twenty hours* after death the heart was removed from the body and Locke's fluid used. The heart remained still at first; after twenty minutes feeble peripheral contractions began, which later extended to the ventricles, and finally the entire heart began to pulsate, and continued to do so for more than an hour. He has repeated this experiment thirty hours after death with human hearts. Velich (1903) was unable to obtain contractions of the heart after the organ had been frozen in salt solution for twenty-four hours.

Experimental Valvular Cardiac Lesions in Living Animals.—The technical skill exhibited by modern physiologists, pathologists, and other laboratory workers in the production of these delicate and highly specialized lesions, without immediately fatal consequence to the animal, is an object lesson on the tolerance of the heart for trauma which should not be overlooked by the practical surgeon. Not only are lesions of individual valves or parts of valves obtained without immediately fatal

results, but the survival of the animal is sufficient to permit a careful study of the primary and secondary disturbances in the mechanism of the circulation which closely imitate the same phenomena caused by cardio-vascular disease in man. Obstructive and regurgitant lesions of the aortic, pulmonary, mitral, and tricuspid valves, and septal lesions imitating congenital deficiencies can now be systematically produced in the laboratory by methods and instruments which have been well specialized by experimental operators. The educational value of such demonstrations when scientifically conducted in training the future clinician is inestimable. This has been clearly shown in this country by W. G. MacCallum, who has adopted the experimental method in teaching pathologic physiology.

Though the surgeon may not be able to profit immediately by these brilliant laboratory accomplishments in cardio-valvular surgery, they have for him at least a twofold interest: namely, they show that with proper methods of hemostasis and comparatively simple technic successful intracardiac surgery (in the auriculo-ventricular chambers) is possible; and that the possibility of correcting valvular defects of pathologic origin, such as mitral stenosis or insufficiency, as suggested long ago by Lauder Brunton, is not such a chimera as many have supposed.

The readers interested in these methods and technic will find numerous references in the Index Medicus, including the contributions mentioned in the papers of MacCallum and v. Haecker.

Causes of Sudden Arrest of Heart Action in Certain Traumatisms.— The sudden, almost instantaneous and fatal, arrest of the heart's movements occasionally observed when punctured or other wounds are inflicted on the heart, especially when the upper interventricular or left atrioventricular regions are involved, have been a fruitful source of experimental investigation and physiologic speculation. In these cases neither the extent of the trauma nor the amount of hemorrhage are sufficient to account for the sudden death. The *region* involved in the trauma, often a mere puncture, appears to be more closely related to the causation of the phenomenon than any other known factor. However, experimental evidence on this point is contradictory.

The supposed Kronecker-Schmey center was called upon for an explanation of this noteworthy phenomenon; a sudden arrest of the heart sometimes occurring in animal experimentation after injury of this supposed center. A number of physiologists, without denying the fact that interference with peripheral contraction of the heart and serious motor disturbances followed injury in the spot indicated by Kronecker (1884), doubted the existence of the Kronecker center, whereas others apparently confirmed it by their experiments, but so far no cases have been recorded in which an injury to the corresponding part of the heart in man produced a sudden arrest. According to the modern myogenetic theory of the heart-beat, the heart continues to work automatically even after it has been severed from all its connections and isolated from all outside nerves. According to this theory, it is difficult to explain the sudden arrest of the heart. The most plausible explanation in this connection would seem to be the inhibition of the heart movements caused by injury to the auriculo-ventricular muscular bundle of His ("Gaskell's bridge," Keith), which

conducts motor impulses from the auricles to the ventricles. Quite recently Erlanger (1905) positively demonstrated that the compression of this bundle is sufficient to bring about the phenomenon of "heart block," in which the auriculo-ventricular movements of the heart become entirely dissociated; and when the injury is sufficiently severe, as Kronecker and Mills proved (1884) in connection with their supposed center, the ordinary ventricular contractions are arrested and a "fibrillar action"—a sort of incoördinated movement of the muscle-fibers—takes place which is absolutely ineffective in expelling any blood from the organ. It would, therefore, be quite possible that accidental injuries to this bundle may be followed by immediately fatal cardiac disturbances. Whether we call it the Kronecker-Schmey center or the muscular bundle of His does not matter for our particular purpose. The fact remains that, on a level with the auriculo-ventricular groove, there is a small area in the heart which controls the rhythmic movements of the organ, which will cause fatal disturbances when permanently injured.

Sudden deaths in injuries of the heart have also been accounted for by reflex action. Afferent impulses would be transmitted from the heart to the medulla and sent back by the pneumogastric. Whatever may be the mechanism by which the sudden arrest of the heart takes place, it is a *fact*, nevertheless, that must be clinically reckoned with. In the course of operations on the heart in man, on a few occasions, the heart has stopped suddenly and finally in systole; and in experimental work the same phenomenon is recorded as occurring quite suddenly and inexplicably. Every-day clinical experience teaches that sudden paralysis of the heart may occur reflexly under the most variable conditions, especially in psychic excitement of all kinds, as the result of so-called mental shock. Surgeons are particularly familiar with the fact that shock and myocardial weakness or paralysis are intimately associated; that certain traumatisms (blows on the testis, on the epigastrium, thorax, larynx, spermatic cord) are followed by sudden arrest of the heart's action, in which exhaustion of the vasomotor center in the medulla appears to be primarily at fault (Crile, 1899; Ehrenroth, Maschke, 1904). Why should not traumatism directly applied to the heart be also capable of occasionally inducing a sudden arrest of its function? As clinicians we must, therefore, bear in mind the fact that this fulminating death in connection with heart injuries most commonly occurs as the effect of severe indirect violence in which there is great shock; it is less frequent in gunshot injuries, and exceptional in punctured and incised wounds. From the practical point of view, as Borchardt says, it is entirely indifferent whether death results in these cases instantaneously by way of the reflexes, or whether it takes place at the end of seconds or minutes only, as the result of hemorrhage or of the mechanical break-up in the heart. When the patient drops dead or dies in a few minutes after injury he is simply inaccessible to any form of treatment. Fortunately, however, these cases are rare.

Simple myocardial wounds may cause death by direct hemorrhage

from the vascular heart muscle (the blood flowing externally), by surgical anemia, or by producing heart compression in a closed pericardium.

Penetrating Wounds.—The effect of these wounds varies with the size of the wound and its character (lacerated, punctured, stab, or gunshot); with the thickness of the ventricle at the site of the injury; the presence or absence of trabecular columnæ carneæ; papillary muscles, which help to arrest the flow of blood; the direction, whether oblique, straight, irregular, or tortuous.

Wounds of the Ventricles.—In equality of conditions wounds of the right ventricle bleed more profusely and are, therefore, more dangerous than those of the left ventricle, because of the greater thickness and greater size of the columnæ carneæ in the left ventricle, which favor thrombus formation. On the other hand, wounds of the left ventricle bleed intermittently with each systolic contraction, the blood-stream being ejected with great force from the wound, even at a distance from the chest-wall, with each contraction. In the right ventricle the flow is almost continuous.

Wounds of the Auricles.—These wounds are regarded by all experimenters and clinicians as more dangerous than those of the ventricles, because the auricles are thinner walled, possess less contractility, and less tendency, therefore, to hemostatic thrombus formation.

Wounds of the interventricular septum are not so dangerous *per se* as those which open the cavities, provided they are not complicated by wounds of the coronary arteries.

As a rule, large cardiac wounds do not tend to close spontaneously; they gape widely, and even have a tendency to increase in size (Bode).

In recent penetrating heart injuries, hemorrhagic and serofibrinous exudates from consecutive pericarditis are almost invariably present, even in the most aseptic cases. There is always some blood-clot in the pericardium. In non-penetrating wounds the seat of the injury is covered by a layer of fibrinous exudation of variable thickness, according to the extent and character of the traumatism. Adhesions usually form quite early between the epicardium and the parietal layer of the serosa; in penetrating wounds the tendency to obliterative adhesions is most marked. These adhesions are partly due to the organization of the bloody extravasation in the sac, but more often to a secondary complicating pericarditis. Extensive adhesions often form without inflammatory signs or characteristic manifestations (Ewald, Payr). The adhesions may be strictly limited to the area of the wound itself, or to the entire pericardial sac. Occasionally the process may continue as a progressive sclerogenic and diffused connective-tissue proliferation, which is described in the section on Mediastinopericarditis. This condition is attended with all the evil effects on the nutrition and the function of the heart previously described in referring to the indications for cardiolysis. Usually the extent and thickness of the adhesions are proportional to the degree and duration of the primary infection, and are always worse in the pyogenic infections. They are relatively insignificant in the aseptic cases.

When the larger branches of the coronary arteries are involved in the traumatism, secondary myocardial degeneration may be expected, though this did not occur in the cases of Capellen and Pagenstecher, in which large primary branches of the coronaries were ligated with no secondary degenerative effects upon the heart muscle. Lesions of the endocardial surface—endocarditis, valvular disturbances, stenosis, and insufficiency, from direct injury to the valves or the chordæ tendiniæ, —occasionally occur, and leave the patient with the characteristic symptomatic and physical manifestations of these defects. In other cases in which perforation of the ventricular or auricular septa occurs, permanent communications or fistulæ remain between opposite cardiac chambers, which in every way imitate the conditions of the congenital defects (*vitium cordis*) which transform the ordinary mammalian into a reptilian type of circulation. In recent wounds of the heart natural hemostasis is obtained, as in other vascular injuries, by the formation of a provisional obturating thrombus which may plug the wound for a variable time after the injury. As the obturating effect of the primary clot passes away and the arterial tension increases, the clot may be washed away by the slightest exertion (cough, straining at stool, sitting up in bed), and thus death may occur within the first week after the injury while the patient is apparently doing well. Loison reports 9 such cases.

In other more favorable wounds, especially of the ventricles, the thrombus remains and organizes, but here recovery is also uncertain, depending largely upon the extent and character of the wound. In larger wounds the tract is only partially closed by scar tissue. A relatively thin cicatrix obturates the external or epicardial opening, while the remaining part of the wound tract persists as an open space connected with the heart chambers, filled with blood, and lined within by endothelium of endocardial origin. This partial cicatrization is followed by a gradual distention of the inelastic connective tissue, which yields to the blood-pressure and gradually develops into a sacculated false cardiac aneurism. These pouches rupture sometimes quite early, with fatal effect. In others early rupture is prevented by the formation of dense adhesions which unite the heart to the pericardium at the seat of injury. The most favorable termination that can occur in unaided natural repair is the obliteration of the wound tract with a connective-tissue plug. True myocardial regeneration is largely prevented in the unsutured cases by the greater size of the organized thrombus which fills the wound tract. Therefore the cicatrix in a spontaneously healed wound remains as a *locus minoris resistentiæ*, which is always a menace to the patient's life. On the other hand, it has been clearly shown by Bonomi, Mariotti, and Elsberg, that heart wounds, when properly approximated by suture, heal by true myocardial regeneration, and with a minimum of connective-tissue proliferation. Hence the advantage of suturing heart wounds, which, if successfully performed, insure a more permanent recovery—free from the histologic weaknesses and physiologic disadvantages which attend large scar formations.

General Etiology, Classification, Localization, and Character of Cardiac Injuries.—The heart is subject to traumatisms of all kinds. Wounds of this organ which are susceptible of surgical treatment, and which are sometimes capable of spontaneous cure, are produced by two kinds of traumatism: (1) By the penetration of the vulnerating body through one or more of the heart-walls; (2) by contusions and crushing injuries which lead to the rupture or laceration of the organ.

The so-called *spontaneous ruptures* or *pathologic perforations* caused by degenerative or other anatomic changes in the heart-wall embrace a large category of cases, the rupture constituting a terminal or complicating phase of myocardial disease in which fatty and fibroid degeneration from coronary lesions, infectious infarcts, ruptured aneurismal dilatations, are the fundamental features. No operative treatment has thus far been recorded for the relief of this class of cases. Surgical intervention is theoretically indicated in their treatment, as in the spontaneous or pathologic perforations of the hollow viscera elsewhere in the body, but the pathologic conditions which underlie the spontaneous ruptures of the heart are of such a character and occur in such forbidding general conditions that no operative intervention can usually be regarded as practicable.

With Fischer, wounds of the heart may be etiologically classified into *punctured, incised, contused, crushed,* and *gunshot,* all of which may be subdivided into penetrating and perforating. Again, some of them may be divided into direct and indirect; also into *external or extrinsic* and *internal or intrinsic,* as in the group of lesions considered under the spontaneous ruptures or perforations.

Fischer, in his great classic, collected 401 cases of heart injuries, which he gathered from the remotest antiquity to his own time. Loison collected 277 additional cases in 1897, and Salomoni, in 1901, added 45 more: the total of all three summing up 723 wounds *not* operated on. In Fischer's group the relative frequency of these wounds is given as follows: Punctured wounds with pointed weapons, 11.3 per cent.; by pointed and cutting weapons (stabs), 66.6 per cent.; by firearms, 21 per cent. Loison, in 1899, in a total of 233 cardiac injuries, found that 49.3 per cent. were gunshot wounds, 40 per cent. stab wounds, and 10.3 per cent. punctured wounds.

In the latest classified statistics of heart injuries *operated upon,* compiled by Rehn at the meeting of the German Surgical Society, April, 1907, we find that 109 were punctured or stab wounds and 15 gunshot wounds, or about 12 per cent. This small percentage of gunshot wounds in the operative cases is identical with the statistics of Lenormant, who, in 128 operative cases from all sources, finds reported only 16 gunshot wounds. This difference in the relative preponderance of the gunshot to other wounds in the non-operated and operated group is explained by Loison, who says that one-third of the gunshot patients succumb immediately or within the first hour after the injury, and in this way give no opportunity for surgical intervention.

Injury of the heart by "impaling" is also recorded (Borchardt). Under the peculiar circumstances of this brutal violence complicated and very grave lesions are produced. Heart wounds caused by fish-bones, bone fragments, and foreign bodies introduced through the esophagus have also been recorded.

Some of the most extensive and frightful injuries are caused by indirect crushing violence, as when the heart is compressed or jammed between the chest-wall by a grinding weight or two opposing forces, as between the bumpers of railway cars, kicks from iron-shod hoofs, falls from great heights, run-over accidents, railroad crushes, etc. The heart may suffer the gravest injuries under these circumstances without a visible external wound. More often there are fractures of the ribs, sternum, or other parts of the thorax. In other cases the heart is only secondarily injured by a stray fragment of ribs or bone which has been forced against it, as in a recent case reported by Travers (Lancet, September, 1906), in which a laceration in the heart produced by a fractured rib was successfully sutured. The gravest indirect injuries of this class are those in which the heart is literally torn and detached at its root—the heart, in fact, has been known to be violently ejected at a distance from the chest wound, entirely severed from all its vascular connections. Bernstein (1905) reports 8 cases of this class.

Localization of Penetrating Heart Wounds; their Relative Frequency and Effects.—There is a statistical difference in the relative frequency of the parts involved according to the source of the statistics, from post-mortem records or from surgical operations. According to G. Fischer, whose statistics are based entirely upon necropsies, 39.2 per cent. involve the right ventricle; 34.4 per cent., the left ventricle; and 8.7 per cent., the right auricle. Oliver, in 61 observations, found that the right ventricle was involved in 47.5 per cent.; the left ventricle, in 19.6 per cent.; the two ventricles, in 44.7 per cent. Zannetti, in a study of 125 cases, states the proportion to be 35.2 per cent. for the right ventricle; 23.2 per cent. for the left ventricle; and 10.4 per cent. for the right auricle. Loison's statistics in the main confirm these older figures and show that gunshot wounds injure the right ventricle only one-half as often as the left. In this way they differ from stab and punctured wounds, which involve more often the right ventricle, the right auricle, and the interventricular groove.

The statistics of the cases operated upon differ from the preceding, showing that the *left* ventricle is involved more often than the right, probably because wounds of the left ventricle are more favorable and permit of a longer survival than those of the right side. Thus Rehn, in the latest compilation, reports that in 124 sutured cases the wound involved the left ventricle in 55 (with 45 per cent. recoveries), and the right ventricle in 50 (with 32 per cent. recoveries). The left auricle was involved in 3 (with 2 recoveries); the right auricle in 4 (with 2 recoveries). In one case the septum was wounded without involving the ventricles; in 11 cases the localization of the wound was not mentioned. Lenormant's collection of 128 cases, published in September, 1906,—which

includes those previously tabulated by Guibal (1905), Borchardt (1906), Spangaro (1906), Tscherniachowsky (1906),—agree with Salomoni's figures and Rehn's later figures in showing the *greater frequency*, and benignity as well, of left ventricular injuries in the cases that survived long enough to undergo cardiorrhaphy. Those of the left ventricle include 58 wounds, with 44.8 per cent. recoveries; of the right ventricle, 49 cases, with 28.5 per cent. recoveries; 5 apex wounds yielded 2 recoveries; the right auricle, 3 cases and 1 death; the left auricle, 3 cases and 1 death. The wounds of the auricles are entirely too few to justify conclusions. That they are more frequently fatal cannot be doubted. All wounds of the auricle involving the septum or the pulmonary artery (once sutured by Mauclaire) ended fatally.

Symptomatology and Diagnosis of Heart Wounds.—There is no pathognomonic sign by which a wound of the heart can be absolutely and unequivocally diagnosed. There are, however, groups of signs and symptoms which, when combined with the history of the case, the seat and direction of the wound, or the probable range and track of the missile, if it is a gunshot wound, make the diagnosis practically certain and unmistakable.

It is not surprising, in view of the numerous complications that are associated with these injuries and the many fallacies that underlie the interpretation of the symptoms and physical signs, that the diagnosis should be beset with difficulties in so many cases.

When a needle or fragment of a weapon is seen sticking in the chest-wall, moving synchronously with the heart, or, as is impressingly described by Homer (Paget):

> "He fell; the spear point quivering in his heart,
> Which, with convulsive throbbing shook the shaft."

Or when the heart is freely exposed in a large wound of the chest with a stream of frothy blood pouring out of it (Körte); or when a wound is large enough to admit the aseptic finger of the examiner, which may, in some cases, be readily introduced directly into the pericardium, and not only feel the heart, but actually plug a bleeding wound in the heart itself (Longo, Giordano), then the diagnosis is self-evident. On the other hand, and quite frequently, the gravity of the symptoms is entirely out of proportion to that of the wound, so that a comparatively trifling wound may be accompanied by the most formidable symptoms; so deceptive, in fact, that in at least two cases experienced operators (Giordano, Sorrentino) have opened the pericardium to find that the heart was uninjured. At other times the outward appearances are remarkably reassuring, while the actual lesions are exceedingly grave and alarming to the careful observer.

Even when the external evidences of heart injury are not so apparent the diagnosis usually can be made with great certainty except in the extreme cases previously referred to. It is a common experience that wounds inflicted in or about the precordium, in the left parasternal region, by sharp-pointed weapons or by a bullet entering at a

distance from the heart, the vulnerating body will penetrate without causing much external bleeding; even a stab wound or knife-thrust of considerable size will not bleed profusely, or be associated with great spurts or pools of blood if the external thoracic wound and that of the pericardium fail to come in apposition. Under these circumstances the bleeding will be concealed internally and the diagnostician will have to depend upon combined signs and symptoms which can hardly be misinterpreted. These are: (1) The signs of internal hemorrhage or acute surgical anemia; (2) the symptom-complex of heart compression or heart tamponade (Morgagni-Rose syndrome), and the physical signs of progressive hemopericardium; (3) physical or auscultatory signs of heart injury; (4) the physical and rational signs of intrapleural hemorrhage.

In nearly 50 per cent. of heart wounds the immediate effect of the injury is to produce unconsciousness, either through psychic or traumatic shock, from which the patient may rally, to develop promptly characteristic signs of internal hemorrhage and vascular depletion. Some, on the other hand, retaining full consciousness, will walk or run some distance or otherwise exert themselves even violently after a perforating injury, and then drop as if fulminated; others may retain consciousness and lucidity of mind until recovery or death. After a temporary rally, whenever the lesion is such as to permit of provisional hemostasis by clotting in the heart wound, the hemorrhage will return with the improvement of the circulation and the consequent displacement of the clot. If the blood finds no outlet from the pericardium, externally or into the pleura, then the signs and symptoms of heart compression will appear progressively in direct proportion to the quantity of blood entering the pericardium. The "Herz-tamponade" then begins, and is indicated by the signs of venous retardation and increased tension of the venous system, due to compression of the auricles. Physical examination at this junction will reveal a rapid increase of the normal area of cardiac dulness which, assuming the characteristic triangular form of a distended hemopericardium, will soon displace the diaphragm downward and stretch laterally far toward the nipple-lines and high up to the level of the second cartilage. At the same time the apex-beat will be felt less distinctly and the heart-sounds will become distant, muffled, confused, and finally inaudible. In the mean time the persistent and increasing venous obstruction by compression of the auricles of the heart will show itself symptomatically by the lividity of the face, cyanosis, bulging, engorged and even pulsating jugulars and other superficial veins. There will be dyspnea, rapid, shallow, labored respiration, and edema of the lungs, showing the blockade in the pulmonary veins; and a progressive steady drop in the arterial tension shown by a rapid, small, thready, compressible pulse, which will stop altogether if the surgeon is not promptly on the scene to *decompress* the heart by freely opening or tapping the pericardium.

While the paramount importance and clinical significance of heart compression and acute hemopericardium are to be borne in mind as indications for immediate interference, it is also important not to over-

look the fact that an acute hemorrhage into the pericardium does not necessarily mean that the bleeding is from the heart itself. An injury to the internal mammary vessels opening into the pericardium; bleeding from an injured pericardial vessel; a bleeding coronary or a puncture of the aorta, pulmonary artery, or any of the great vessels at the root of the heart, within the pericardial sac, may all fill up the pericardium, and, after distending it, cause the symptoms of heart tamponade. The importance in value of the Morgagni-Rose syndrome in the diagnosis is, therefore, simply as an indication for immediate surgical action, which will permit of a more positive diagnosis of the exact lesion after the exploration.

When the pleura and the lung are both involved in the heart injury, the blood will escape from the pericardium into the pleura, and there will be no heart compression; then, if air gains admission into the pericardium, as well as into the pleura, tympanitic resonance will take the place of the triangular area of dulness, which is so diagnostic of pericardial hemorrhage. In this way the entire picture of heart injury will be obscured and blurred by the pleuro-pulmonary signs, and the attention of even the most careful observer may be erroneously transferred from the heart to the lungs and pleura. Even under these circumstances a careful examination of the heart-sounds will suggest that serious cardiac lesions have been inflicted. The normal heart-sounds will be accompanied by strange "bruits," such as the "water-wheel" or "mill-wheel" bruits, "splashing," "whistling," "gurgling," and aneurismal sounds will also be heard, suggesting the abnormal formation of eddies in the heart and the churning of air and fluid in the pericardium. Again, as Nietert has observed in cases in which hemothorax is progressing, the intermittent spurt of blood from the heart into the pleural cavity may be accompanied by a splashing sound eminently suggestive of the flow of fluid into a hollow cavity. This bruit can be present only when pneumothorax is associated with the pleural perforation. Again, the occurrence of severe vomiting with abnormal muscular tension and reflex rigidity of the epigastrium has repeatedly led to a mistaken diagnosis of abdominal injury (Rassieur, Guibal, Marion). This reflex rigidity is as characteristic of acute lesions of the supraphrenic as it is of the subphrenic areas.

While it is always desirable and important to make as accurate a diagnosis of the seat of the heart injury as possible, the surgeon can afford to act without the absolute certainty of heart injury in the presence of urgent symptoms calling for an exploring pericardiotomy. We believe that, in the thorax, as in the abdomen, when there is doubt, exploratory operations are perfectly justifiable (especially with the improved technic of exploratory pericardiotomy) in the presence of such symptoms. If there is a wound of the precordia or parasternal region, bleeding so profuse that fatal syncope from acute vascular depletion will follow if it is not stopped, the surgeon should proceed to the immediate exploration of the wound after thorough aseptic precautions have been taken. The wound should be enlarged

freely in the interspace that is involved and the hemorrhage followed to its source, wherever this may be. By the simple intercostal incision of Spangaro a large opening may be rapidly made which will permit the pericardium, pleura, lung, and heart not only to be exposed, but also to be treated. On the other hand, if there is no parasternal wound, as often happens in gunshot cases, and there is decided evidence of hemo-pneumo-pericardium or of progressive hemothorax with heart signs, or if the still more important signs of heart compression are evident, there should be no delay in opening the chest and reaching the heart as quickly as possible.

To sum up: visible external hemorrhage, hidden or concealed hemorrhage, and, above all, signs of heart compression, call for *immediate exploratory thoracotomy* by the methods described in the section on Treatment. Nietert, who operated upon 4 cases of penetrating wounds of the pericardium in which there was bleeding into the sac, with a coincident wound of the pleura, noticed that, in all his cases, the characteristic splashing sound was present. He believes that, when the pericardium is closed, this sound cannot be produced; that it is, therefore, of differential diagnostic value in cases of cardio-pericardial injury associated with pleural perforation.

A point of some interest is mentioned by Borzymowski, and Tscherniachowski, who both noticed that in the two patients operated upon for heart injury by them the radial pulse was absent on the left side. This peculiarity, which was not easily explained, if not a coincidence, may prove to be a valuable diagnostic sign.

The *x*-rays are of relatively little practical value in the more urgent class of cases; patients with bleeding heart wounds are in no condition to undergo radiographic examination. Only when foreign bodies (needles, bullets, etc.) are present or suspected will it be advantageous to subject the patients to *x*-ray, fluoroscopic, or radiographic examinations. When it has been decided that the extraction of a foreign body is necessary, then the *x*-rays are indispensable in definitely localizing the foreign body. Then it is that special advantages may be obtained by the use of the compass of Contremoulins, which was so helpful to Tuffier in his comparatively recent case of extraction of a bullet which had become encysted on the surface of the right auricle. This group of cases (foreign bodies) usually presents no urgent symptoms and the patients can be examined deliberately and leisurely.

Here we have considered the more urgent indications which apply to all classes of heart injury regardless of causation. The extraction of foreign bodies can be considered with more deliberation, as will be seen in the sections devoted to these subjects.

Clinical Career, Complications, and Terminations of Heart Wounds.—The clinical career and termination of cardiac injuries, when allowed to pursue their natural course without operative intervention, is extremely variable. The cases may be divided, as Borchardt suggests, into three groups: The *first group* is represented by the gross traumatisms caused by crushing and grinding injuries, run-over accidents,

falls from great heights, explosive effects of bullets, etc., in which the heart is torn and destroyed *en masse*. It includes also all cases in which death is instantaneous from shock or other direct nerve influence. Of these victims, Riedinger says: "They do not die, they are dead" before any assistance can be rendered. The *second group* includes those patients who survive their injuries a few hours or a few days. These are the cases in which hemorrhage—concealed hemorrhage into the pericardium and into the pleura—plays the leading part, and which furnish the largest contingent of operative cases. These are the cases of penetrating or perforating wounds—punctured, stab, and gunshot—in which heart compression or progressive anemia demand the greatest attention in order to perform opportunely a prompt intervention, which is necessary to prevent inevitable death. The great majority of cardiac injuries belong to the second group. The *third group* is formed by the small number of patients who apparently survive their injuries, who, after going through a critical period of great doubt and uncertainty, in which the issue remains doubtful for days and weeks, finally recover. However, even in these apparent recoveries, death may come on suddenly and when least expected, owing to secondary hemorrhage into the pericardium caused by the displacement of imperfectly organized clot or the yielding of the cicatrix in the wound.

In addition to the danger of secondary hemorrhage into the pericardium from imperfect cicatrization, other grave dangers threaten the patients. Death may occur from the migration of emboli into the pulmonary artery when the right auricle or ventricle is involved; to the brain, causing hemiplegia, and to other organs, when the left auricle or ventricle is injured. The secondary complications from disturbed action, injury to valves, cardiac aneurisms, persistent arteriovenous fistulæ, by perforation of the septal walls and pericardial adhesions, remain more or less as permanent disabilities. The presence of foreign bodies or the migration of bullets are merely mentioned here as contributors to the general impairment of heart function which follows these injuries. Finally, the most formidable complication which the patient has to face, after surviving the immediate effects of the primary injury, is infection, introduced into the tissues with the vulnerating body. As a consequence, pericarditis of various degrees of virulence may follow with extensive adhesions; myocarditis, coronary infarcts with secondary degeneration of the heart muscle, endocarditis, empyema and chronic pneumothorax, are among the complications which tend to make the post-traumatic history of these patients most uncertain and precarious.

Treatment of Heart Wounds.—The rational treatment of heart wounds is entirely a modern achievement. "Up to the eighteenth century very little, indeed, was done for the unfortunate patient. The external wound was closed, and the patient was packed in ice. The chest was surrounded with a rampart of ice-bags, the room was cooled off below zero, if possible, and whenever this was not feasible in summer, the patient was transferred to the cellar." This procedure, which

somewhat suggests the modern preservation of cadavers, was not only seriously proposed, but actually carried out (Borchardt).

When Rose demonstrated the correctness of Morgagni's explanation of the cause of death and impressed the surgical world with his vivid interpretation of the symptoms of heart compression, venesection was added to the routine methods of palliation, viz., cold to the pericardium, *absolute* mental and bodily rest, moderate stimulation with alcoholics, and the use of opium or morphin hypodermically, which is still one of the best auxiliaries of the surgeon in relieving pain and shock. Subsequently, the far more rational plan of relieving the heart compression by direct tapping of the pericardium was adopted, and in this way many cases of hemopericardium caused by small wounds or perforations were successfully tided over, while permanent hemostasis was obtained by the organization of the provisional thrombus in the wound. At present there is still an opportunity for the palliative or expectant treatment in some cases—in which there is a combination of mild symptoms with a doubt and uncertainty in the diagnosis, the symptoms not being urgent enough even to justify an exploratory pericardiotomy. On the other hand, there can be no hesitation or doubt as to the surgeon's attitude, however, when the symptoms are grave, progressively more imperative, and menacing. Then the call to operate is mandatory and must be heeded if life is to be saved.

The Operative Treatment of Cardiac Wounds.—This may be considered under the following headings:

(*a*) Thoracotomy, by which an opening is made into the thorax.
(*b*) Treatment of coincident injuries of the pleura and the lung.
(*c*) Opening of the pericardium.
(*d*) Cardiorrhaphy, or suture of the heart wound.
(*e*) Drainage of the pleura and of the pericardium.
(*f*) The post-operative treatment.

Thoracotomy.—One of the most striking evidences of the profound interest aroused in the last decade in the surgery of the heart, and also of the almost incredible developments of this new department of surgery, is offered by the bewildering multitude of procedures and their modifications that have been suggested to obtain access to the pericardial cavity and the heart. This multiplicity of methods is characteristic of the formative period of any department of technical knowledge in which the crucial test of experience is only of recent acquisition, and as to which definite judgment has not yet crystallized. What are wanted are a few fundamental principles and a limited number of practical suggestions and methods which illustrate the resources of the modern technic.

The vast majority of the procedures which open the thorax with a view to exposing the pericardium and the heart have been grouped in the precordial region, between the left edge of the sternum and the left nipple-line, extending above to the second and below to the seventh rib. These are designated as the *left parasternal methods*, which may again be subdivided as follows:

(I) (1) Simple intercostal incisions which do not involve the skeleton of the thorax and include only the soft parts. Usually these are associated with secondary divisions of the costal cartilages at the chondrosternal junction.

(2) Thoracotomy with excision of the costal cartilages and ribs.

(3) Osteoplastic resections or solid trap-door flaps, which contain sections of cartilages and ribs. These again may be subdivided into those in which the flaps fold on a horizontal line upward, with trap-doors which open downward; with double trap-doors which open up and down; with vertical hinges which fold over toward the sternum, or outward toward the mammary line.

(II) The second group involves the sternum exclusively (thoracotomy by the sternal route; temporary osteoplastic resection, Fontan; partial sternectomy, Morestin; Cantas).

(III) A still smaller group—the right parasternal region, to the right of the sternum.

(IV) Lastly, the transdiaphragmatic or abdomino-diaphragmatic route, via the peritoneum, mentioned chiefly to meet the historic requirements of classification.

In addition, the procedures may also be considered from the point of view of involvement of the pleura, by dividing them into two groups, the transpleural and the extrapleural methods. All the osteoplastic methods, trap-doors, etc., are necessarily of the transpleural type; the extrapleural methods are few, and are best represented by the Kocher, Sandulli, and Lorenz operations. (For full details, consult the monographic works and articles of Terrier-Reymond, Salomoni, Guibal, Borchardt, Wendel, and Rehn, referred to in the Bibliography.)

The rapidly increasing experience in this field of surgery accounts for the growing tendency displayed by the most thoughtful writers toward greater economy in the operative work, a greater simplicity in the technic, and a marked indisposition to adopt the "typical" transpleural or osteoplastic resections, especially in the absence of a positive diagnosis. The demand is for a simple preliminary exploratory operation that will permit an investigation of the pericardium and of the heart, without the addition of a pleural perforation. This simple preliminary exploration is necessary in order to determine positively: (1) the existence or non-existence of a heart wound; (2) the part of the heart that is injured; and (3) the associated complications or injuries. In this way the principles now governing intraperitoneal explorations in uncertain and doubtful abdominal cases will be similarly applied to the pericardial serosa and its contained organs.

Methods of Election.—All operable cases of heart injury resolve themselves into two great groups:

Group I.—Suspected or doubtful cases, calling for exploratory pericardiotomy. In these the heart lesion is only suspected or diagnosticated without the suggestive aid of an external wound in the anterior thoracic

region or in the immediate precordia. This occurs more often in gunshot wounds in which the bullet has penetrated the thorax at a distance from the heart (lateral, posterior, and upper thoracic regions, abdomen); in indirect injuries, when sharp bodies penetrate through the esophagus, and in ruptures from indirect violence, falls, etc. In this group of cases the surgeon must proceed, in the presence of the physical and rational signs of heart injury, especially heart compression, by the most direct route consistent with two conditions: (1) That no complications shall follow (pneumothorax) if the exploration proves negative; (2) that it shall permit a free exposure of the heart and pericardium by merely extending the lines of the preliminary exploratory incision.

These requirements are met quite satisfactorily by any of the incisions recommended for pericardiotomy which radiate from the left lower chondrosternal angle, immediately over Voinitch's safe triangle or interpleural space; *namely, the left edge of the sternum, including the attachments of the fifth, sixth, and seventh left costal cartilages.* Several "typical" procedures have been described which meet all the requirements of an exploratory pericardiotomy, differing very little from each other except in the costal cartilage that is selected for excision as the initial point of entrance into the thorax. No serious accident can befall a cautious operator who selects either the fifth, sixth, or seventh costal cartilage as his initial point of attack, provided he adheres closely to the perichondrium and makes his way into the mediastinum by a process of enucleation or shelling of the cartilage or bone without injuring the soft parts until the firm, fibrous pericardium is felt and exposed. After the removal of the cartilage it is easy to make more space by gnawing a fenestrum out of the left edge of the sternum with a rongeur. Therefore, either of the routes shown in the accompanying diagram (Fig. 20) will be considered safe for an exploratory pericardiotomy. Slight preference is given to Kocher's (sixth cartilage) or Ollier's procedure (fifth cartilage), because they are not only safe as far as the pleura is concerned, but they are further from the diaphragm than the seventh cartilage. It will be noticed that while I give the preference to the lower sternal or parasternal route for draining purulent pericardial accumulations (as these drain the pericardium in its most dependent portion), I

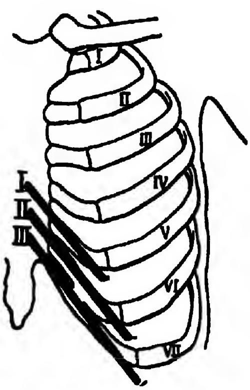

FIG. 20.—LINES OF INCISION FOR EXPLORATORY PERICARDIOTOMY WHICH RADIATE FROM THE LEFT STERNOCHONDRAL ANGLE, INCLUDING THE FIFTH, SIXTH, AND SEVENTH COSTAL CARTILAGES.

I, Incision for resection of fifth costal cartilage and edge of sternum, proposed by Ollier (1891), C. B. Porter and Durand (1896), etc.; II, resection of sixth cartilage and adjoining sternum, proposed by Kocher (1903), Voinitch, etc.; III, resection of seventh costal cartilage, proposed by Mintz (1904), Rehn (1907), etc.

prefer the costal resections at the left lower chondrosternal angle for exploratory purposes in suspected heart injuries and in relieving traumatic hemopericardium. This route is preferred because it permits of easy extension in an upward or lateral direction (in accordance with the suggestion of Durante or Spangaro) should a wound of the heart be confirmed and a cardiorrhaphy be required.

Kocher's Method.—"An angular incision is made, the one limb passing down the middle line of the sternum, the other running outward along the sixth left costal cartilage. The periosteum of the sternum and the perichondrium of the sixth left costal cartilage are stripped back along with the pectoralis major until the elevator can be passed behind the costal cartilage, which is then divided with forceps close to the sternum, and, if necessary, including a bite of this bone. In the lower and outer part of the incision the attachments of the pectoralis major and the rectus abdominis are separated along the upper border of the sixth rib. The cartilage is stripped of all the overlying soft parts. The triangularis sterni is then exposed, with the internal mammary vessels lying on it. The tendinous attachments of this muscle to the sternum and the sixth costal cartilage are carefully divided, and the internal mammary artery and vein are ligated if the branches going toward the middle line are well developed. By passing the finger into the cavity left by the removal of the sixth rib the tough, glistening pericardium can be reached. If necessary, the pericardium can now be punctured or incised. *The edge of the pleura,* distinguished by the pad of fat covering it, is pushed aside by the finger and raised from the pericardium. The intercostal muscle, along with the internal mammary vessels, is pushed aside with the pleura, as, according to Delorme and Mignon, it is firmly adherent to it. If a gush of blood flows from a wound in the pericardium, thus confirming the diagnosis of cardiac injury, the finger may be introduced so as to explore the heart itself and ascertain, if possible, the position of the wound. The persistent flow of blood from the pericardium will justify an immediate enlargement of the thoracic fenestrum by dividing the fifth and even the fourth or third cartilages, which are carefully raised at their sternal attachments. At the same time the pleura is stripped back from their under surfaces; unless this is done carefully, the pleura is liable

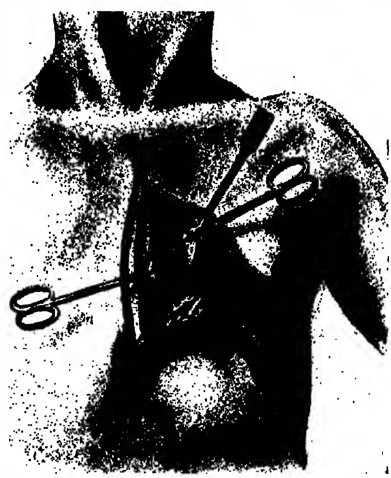

FIG. 21.—SHOWS THE APPEARANCE OF THE WOUND AFTER ADOPTING THE DURANTE ⊢-SHAPED EXTENSION IN A CASE OF HIGH-PLACED PENETRATING WOUND. (From Rehn.)

The pericardium and the heart are freely exposed by an intercostal incision and by forcibly retracting the cartilages of the ribs at the divided sternochondral angles.

to be torn. In this way the three costal cartilages and the muscle attached to them are thrown upward, and, by wrenching the cartilages from their attachments to the ribs, they can be folded backward as one chondroplastic flap. By dividing the pericardium along the edge of the sternum and outward along the line of the fifth intercostal space the heart can be inspected and palpated from the auricles down to the apex" (Kocher, 1903). If more room is required, it is easy to enlarge the space by supplementing the vertical by a transverse intercostal incision, which can be carried out toward the mammary line as far as may be necessary. In this way a double triangular flap is obtained, with the apices meeting at the point of intersection (Durante's procedure, Fig. 21). This space is again increased by vigorously retracting the flaps and ribs upward toward the clavicle, and the lower flap downward toward the abdomen.

FIG. 22.—REHN'S MODIFICATION OF KOCHER'S EXPLORATORY PERICARDIOTOMY. (From Rehn.)

The sixth and seventh ribs and cartilages are retracted. The pericardium is brought out to the level of the skin; a small opening is made and the edges of the incision are held apart by the three clamps as shown in the figure. This operation to be preferred in all cases in which the coincident perforation of the pleura is doubtful.

Rehn (1907) modifies Kocher's incision as follows (Fig. 22): A curved incision is made to follow the lower margin of the seventh left rib, about 6 cm. in length, toward the base of the ensiform process, passing obliquely around it. The edge of the sternum and the adjoining seventh costal cartilage are removed with rongeur forceps, the sixth costal cartilage being resected also if necessary. By working upward with the finger under the sternum, injury to the peritoneum is also avoided. It is extremely easy then to open the pericardium and to inspect its contents. The edges of the pericardial wound are caught in the bite of forceps and brought readily to the surface, where they may be sutured to the pectoral aponeurosis or even the skin if permanent drainage is decided upon. If the pericardiotomy reveals a wound of the heart which is not accessible by this exploratory incision, the incision can be prolonged upward along the edge of the sternum and outward along the sixth interspace toward the mammary line forming a triangular flap, which can be readily elevated by retraction in the manner described in the paragraph on Kocher's incision or Spangaro's method.

Ollier's operation (1891) reaches the pericardium by resecting the fifth costal cartilage. It was independently advocated and adopted in this country by C. B. Porter, whose admirable contributions have made this route more familiar and acceptable to American surgeons than any other. "An incision is made from the middle of the sternum outward over the fifth costal cartilage to its junction with the rib. The soft parts are cleaned from the cartilage with periosteum elevator, care being taken not to wound the pleura on the under surface. The cartilage is removed with bone forceps. The mammary artery and vein are thus exposed, ligated in two places,

and divided. A little careful dissection with the director, in case fat is encountered, exposes the pericardium, which is normally much thicker than the pleura."

In adopting any of the procedures above described for exploratory purposes, the operator can readily attain his object by applying the muscle-splitting principle of McBurney. A vertical incision, which will permit the division of the left rectus muscle in the line of cleavage of its fibers, is then made. This will permit the resection of the cartilages and of the sternum, allow drainage to be established, etc., without weakening the abdominal wall, as is the case when the initial incision is made transversely and parallel with the costal arch.

Group II.—In this group of cases a bleeding wound in the precordial or parasternal region (60 per cent. of the cases) already exists. This furnishes a direct guide to the heart, confirms the diagnosis of injury of this organ, especially when the outpour of foaming blood, a crepitating subcutaneous emphysema, as well as the physical and rationa signs, suggest plainly that the pleura has been perforated in addition to the cardiac injury (80 per cent. of the cases). For these cases the intercostal incision, recommended and systematized by Spangaro, of Padua (1906), is best suited to meet the requirements. Spangaro originally devised and planned this simple method independently of Durante's original suggestion, as also of Mikulicz and Sauerbruch (1905), who applied it to reach the esophagus in the posterolateral region of the thorax. It has received the emphatic approval of Salomoni at the Congress of Italian surgeons of 1906, and of Rehn at the German Surgical Society, April, 1907, and has proved most satisfactory in actual practice in the hands of Wilms, who applied it independently, without previous knowledge of Spangaro's publication. This method is so simple that it is surprising it should not have been thought of long ago. It entirely supplements all previous methods, and is to be recognized as the method of election in all cases in which there is an external wound in the precordia to guide the surgeon to the pericardium. With other precautions, as Rehn suggests, it may be utilized also as a *typical* procedure when the original wound is situated at a distance from the precordia, by beginning the operation with an incision in the fifth left intercostal space. Ordinarily, when the external wound lies near the sternum, the wound is merely enlarged and followed downward to the pleura in the middle of the intercostal space, to avoid the intercostal vessels. If perforation of the pleura is confirmed by the presence of air or blood in the cavity, the incision is carried at once into the pleural cavity, and is continued horizontally along the intercostal space to a point 2 cm. from the left margin of the sternum, where the internal mammary vessels are exposed. These are divided between two ligatures, and the incision is carried through the whole thickness of the interspace to the left edge of the sternum. The incision, always in the interspace, may be prolonged outward as far as desired, being rarely required beyond the anterior axillary border. By forcibly retracting the ribs with the

fingers in the incision, the interspace can be enlarged sufficiently to obtain a good view of the pericardium, heart, pleura, and lung; by merely dividing the cartilage at the chondro-sternal joint, immediately

FIG. 23.—SPANGARO'S INTERCOSTAL INCISION—PERICARDIUM EXPOSED.

above or below the intercostal incision, the retraction of the ribs will be immensely facilitated and a large view of the heart and pericardium will be obtained, sufficient usually for all manipulations on the apex or

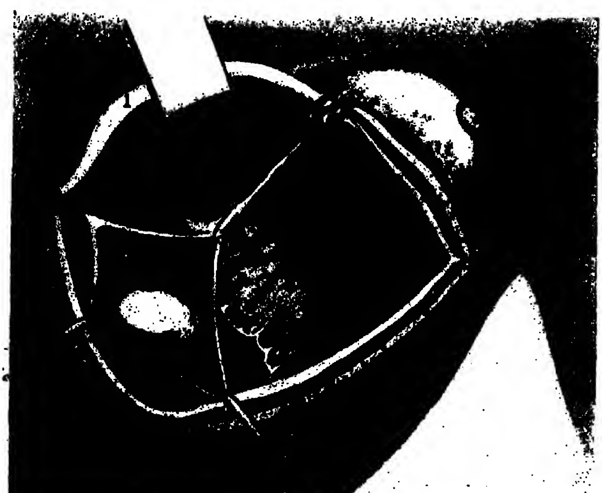

FIG. 24.—SPANGARO'S INTERCOSTAL INCISION—PERICARDIUM OPENED.

ventricles of the heart. If more space is required to reach the auricles or posterior surface of the heart at the base, the simple division of the cartilages at the sterno-chondral junction up to the second cartilage

above or to the sixth below will amply suffice to meet all requirements; if for some extraordinary and very exceptional reasons still more space should be required toward the right, the intercostal incision can be prolonged horizontally over the sternum and this bone divided either with the Gigli saw or bit away by the rongeur, after carefully stripping back the periosteum and the margin of the right pleura. This will permit, by its retraction and elevation, and by resection, if need be, a still larger increase of space. However, this necessity will scarcely ever arise. It is readily understood that the motility and elasticity of the ribs will permit of an enormous retraction and widening of the intercostal spaces after the chondro-sternal joints have been divided at the sternal end of the incision. (See Fig. 25.) Furthermore, it is easy, in any event, to luxate the costal cartilages outward toward the mammary line should a wider outward space be required. Wilms, in reporting his case in which two wounds of the heart were sutured,—one about the middle of the left ventricle anteriorly and the other at the same level posteriorly,—states that suture of the posterior wound could never have been accomplished by a typical osteoplastic method unless the sternum had been divided on the same level and a section of it turned out as a trap-door. As it was, Wilms succeeded perfectly in expeditiously accomplishing his purpose by making a *long intercostal* incision in the fifth intercostal space. In addition to the heart wounds, a wound in the lung was also sutured through the same incision. The patient made an uninterrupted recovery. Through the fenestrum created by Spangaro's intercostal incision the hand of the operator can enter freely into the chest and explore its contents. Furthermore, the diaphragm, lungs, and deeper recesses of the cavity can be explored visually by direct or electric illumination.

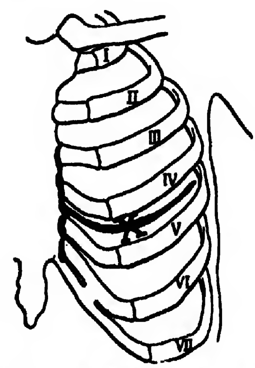

FIG. 25.—DIAGRAM TO SHOW HOW THE SPANGARO INTERCOSTAL INCISION CAN BE AMPLIFIED BY MAKING A CHONDRO-STERNAL DISARTICULATION.

This converts the simple intercostal incision into a horizontal T, as Durante, Rehn, and others have suggested. By forcibly retracting the sternal angles of the incision, all the space required to expose the pericardium and heart can be obtained. When the interspaces are narrow and the cartilages and joints are ossified, this modification may be especially advantageous. The mark X indicates the theoretical position of a wound in the precordia.

To sum up this discussion on the route of access to the heart and pericardium by thoracotomy, we arrive at the following conclusions:

(I) In all cases of doubtful diagnosis, in which there is no certainty that the pleura has been opened, in which there is no pneumothorax, and in which there is no wound in the parasternal or precordial regions which could be enlarged for exploratory purposes, adopt the Kocher operation or one of the same type, as previously described.

(II) When the existence of pneumothorax is made certain by the physical signs or by the appearance of an external wound in the precor-

dial or parasternal region, and the fact of the perforation of the pleura is confirmed by the exploration of the external wound, the quickest and safest route to the pericardium and the heart is by Spangaro's intercostal incision just described.

Treatment of Associated Pleuropulmonary Lesions.—The need of protecting the pleura from accidental injury has been sufficiently insisted upon not to require repetition; unfortunately, in over 80 per cent. of all cases the pleura is opened by the vulnerating body, and pneumothorax, to a greater or less extent, already exists when the surgeon is called upon to operate. If the lung is injured coincidentally and this is discovered while the heart is being exposed, the lung injury, if it is not bleeding profusely, may be disregarded until the work on the heart is completed. But if the lung is bleeding freely, temporary hemostasis should be obtained by gently clamping the bleeding surface with broad oval or triangular clamps.

In extensive injuries of the anterior thoracic region and in the course of operations by the sternal route to the heart both pleural sacs may be opened, and in this way an acute double pneumothorax may occur with almost immediately fatal effect. In these desperate circumstances, as well as in the cases in which the sudden rush of air collapses the lung on one side and asphyxia is threatened, artificial respiration may be kept up rhythmically with the Fell-O'Dwyer apparatus until the operation is completed, both pleuræ being closed. After the thoracic wound is sutured the pneumothorax may be relieved by aspiration, as suggested by Delagenière.

While it is a fact that in none of the cases of cardiorrhaphy thus far reported artificial means of inflating the collapsed lung have been applied, and repeated successes have been obtained in spite of respiratory disturbances, there can be no doubt that mechanical means of maintaining the respiratory rhythm, when the pleura is opened, would prove of the greatest utility in many instances if judiciously applied.

Sauerbruch and Haecker, who have most recently studied the effect of artificial respiration in the treatment of heart wounds, complicated with pneumothorax, attribute much of their success, while operating on animals, to the help obtained in regulating the expansion of the lung while the animals were kept in Sauerbruch's chamber. They observe that hemorrhages from heart wounds are very materially lessened by the coincident collapse of the lung caused by the inrush of air when the thorax is opened. Therefore, the primary collapse of the lung is desirable in the first stage of the operation until the heart wound is sutured. After this, the pneumothorax is harmful and dangerous, as the vigor of the heart's action diminishes and the blood-pressure falls progressively with the persistent failure of the respiration as long as the collapse of the lung continues.

As soon as the respiratory function is re-established by artificial means, the heart's action improves and the systematic blood-pressure returns.

The general conclusion reached is that artificial respiration with mechanical contrivances (whether on the "*minus* pressure" principle, Sauerbruch's chamber, or the "*plus* pressure" principle, Brauer, Meyer, Fell, O'Dwyer, Doyen, Matas Smyth pump, Green's, Robinson's, etc.) is not required or may even prove injurious in the first stage of thoracotomy and during the act of suturing the heart; but this is of decided value in the terminal stages of the operation, when the respiration and

circulation both begin to fail, and when it is necessary to obliterate the pleural space made vacant by the collapse of the lung.

More serious even than the pneumothorax is the danger of the simultaneous infection of the pericardium and the pleura, due to neglected asepsis during the hurry of the operation, or from primary infection introduced by the weapon into the wound, this last cause being less important as a factor in the problem than the first. Pleuro-pericardial infection is the most serious obstacle to permanent success in cardiac surgery, and justly demands the most scrupulous care on the part of the surgeon in his antiseptic preparation.

Opening of the Pericardial Sac.—The sac may have been opened already by the weapon, leaving very little blood in the pericardial cavity, the hemorrhage finding an exit externally or into the mediastinum or pleura. More often the pericardium will be found distended, holding the blood that flows from the heart in spite of a small perforation or opening which is perhaps temporarily blocked by a clot or by the heart itself. It is always best to open the pericardium freely throughout its long axis, from the level of the apex to the base, so that the bleeding wound may be quickly reached by the hand of the operator. The edges of the incision are then seized with long-handled hemostats, by which the free edges of the pericardium are pulled out to the level of the external wound, thus making the heart more accessible. When the pericardium is tightly distended, the immediate relief of tension brought about by the escape of the pent-up blood will at once improve the heart's action, and a favorable change in the general circulation will follow. The patient is then likely to become sensitive, to recover some consciousness, and it may be necessary to anesthetize him to keep him under control. If there has been no heart compression and the heart is comparatively still from shock and depletion, it may be easy to recognize the wound at once. More often the heart's action is violent and tumultuous, and the field of the operation is deluged with blood which gushes out in intermittent streams, spurting sometimes beyond the wound in the thorax or folding up into a mass of froth which pours out of the external wound in large quantities. This is especially true of the cases complicated with a large opening in the pleura, which allows the air to rush in and out of the thorax with each respiratory movement and mix with the blood, the heart churning and lashing it into a thick crimson foam which entirely envelops the organ and hides it from the view of the operator. This was my own experience in a case operated on in the Charity Hospital of New Orleans in 1897. (See Bibliography.) In these imposing circumstances it is impossible to see the wound, much less attempt to suture it. Sponging or mopping is worse than useless. There is but one alternative. The operator must then resolutely do one of two things: he must thrust his fingers into the pericardial sac through the swirl of blood and endeavor to locate the wound by palpating with his fingers, and then plugging it with the finger-tips, if he finds it; or he must grasp the heart with his

whole hand and drag the bleeding and writhing organ massively out to the thoracic wound, where, by gradually relaxing his grasp, the seat of the hemorrhage will be certainly identified[1] and the suture can be readily applied. Rehn has proved experimentally that the most effective way of obtaining hemostasis for the few seconds required to suture the wound is by grasping the root of the heart on a level with the right auricle and compressing the venæ cavæ at their entrance into the auricle. (See Experimental Data, and the Physiopathology of the Wounded Heart, p. 42.) This compression can be kept up continuously or intermittently long enough, and is less injurious than the violent massive compression and traction of the organ to which some operators have found it necessary to resort in order to stop the flood of blood. In the presence of profuse hemorrhage in the pericardium it is the duty of the operator to inspect the entire surface of the heart up to the roots of the great vessels to make sure that he has secured the bleeding point. Failure to do this and the assumption, without proof, that the hemorrhage may come from other sources, has led several operators to overlook the real cause of the bleeding, leaving the patients unrelieved by the intervention.

Cardiorrhaphy.—As a general principle, all wounds of the heart of sufficient gravity to call for exploratory thoracotomy should be sutured (Guibal). It must be remembered that incomplete wounds which do not perforate the walls of the heart may enlarge and finally perforate under endocardial pressure. A few happy cases in which wounds of the heart terminated by recovery, without suture, after they have been exposed, are recorded. On the other hand, there are cases in which the failure to suture the wound after the heart has been exposed by operation has ended in death from secondary hemorrhage.

In suturing wounds of the heart which bleed profusely provisional hemostasis must be secured; the heart must be steadied and immobilized as much as may be compatible with its function, and a good suture technic must be adopted. Provisional hemostasis may be obtained by digital obturation of the wound, as above described. Ninni controlled a hemorrhage by plugging the wound with the little finger of his left hand, while he used his right to enlarge the thoracic opening. Bullet forceps or clamps of any sort should never be used as tractors, because they are liable to tear the myocardium and lacerate the edges of the wound. The better plan is to hold the heart by the apex and pull it up gently until it is brought to the external wound, where it can be seen or sutured. Guinard recommends that the heart be seized over the left ventricle; this gives a much better hold than the right ventricle, and, by placing the thumb of the left hand over the anterior interventricular septum, the index-finger over the thick edge of the left ventricle, and the middle finger under the apex, the heart, which otherwise would slip away easily, will not escape from the operator's grip and can be brought safely to the

[1] The reader will find the most graphic account of the thrilling circumstances in which this procedure may become necessary in Guinard's extremely interesting report of his personal experience with a heart wound of this kind.

surface for suture. In dealing with wounds of the posterior surface and at the base it may be necessary to lift up the heart by its apex and turn it upward so as to expose the posterior surface (Launay), or partially to twist the heart on its axis from right to left (Bouglé).

By the maneuver so graphically described by Guinard the tumultuous movements of the heart are largely controlled and hemostasis is at once obtained. The digital method of fixation is far preferable to any of the various methods of holding the heart that have been tried and recommended, such as pulling on the apex with forceps; traction with a loop of thread passed through the apex (Spangaro), etc. It is important that the wound be well exposed and brought near enough to the surface for a deliberate suture. A curved, round intestinal needle or a milliner's straight needle, held in a light but firm holder, should be used. The majority of operators in Europe have used silk; latterly, the tendency has been to use chromic gut more often. However, one death is attributed to the loosening of catgut sutures (Schoenborn). According to Goebell's recent and extensive experiments on heart suture to test the repair of these wounds, antiseptic silk is to be preferred, as it appears to leave a firmer and more resistant cicatrix.

In passing the suture a considerable margin of the myocardium should be taken, the needle penetrating through the thickness of the muscular wall down to the endocardium, but not through it, the point of the needle being again introduced at the very edge of the endocardium, so that when the suture is tied, the thread will not appear inside of the heart chamber. The suture should be applied to the heart in accordance with the principles which govern arteriorrhaphy as applied to the large vessels. Several operators have passed through-and-through sutures (Guinard, Gibbon, Fontan, *et al.*), and their patients have escaped the dangers of embolism and thrombosis (except Fontan's), which may be apprehended when the thread is exposed in the heart cavity in contact with the blood. When the sutures are nicely approximated, however, even when they perforate the entire thickness of the heart wall, they are not likely to appear in contact with the blood, and, by bringing the endocardial serosæ in firm and perfect apposition, there will be little if any danger of thrombosis or embolism. Sometimes thrombi form in the ventricle on a level with the wound without perforating sutures.

The introduction of the first suture is the most important step in the process. After this has been passed, the edges of the wound are well steadied by gentle traction upon the thread after the knot has been tied. While the heart is steadied by the hand, which also holds the long end of the first suture, the other sutures can be passed either continuously or as interrupted sutures at a short distance apart, to secure close approximation and total obliteration of the wound.

There is still considerable discussion as to whether the continuous or interrupted sutures should be used; the majority thus far have preferred the interrupted sutures, as showing less tendency to myocardial necrosis than the continuous sutures (Elsberg). It is argued against the continuous suture line that if a single thread cuts through, the entire suture

will be a failure. This question will have to be decided largely by the individual preference of the operator, who should adopt that mode of suture with which he is most familiar and which can be most conveniently applied at the time. In several cases the myocardium has appeared to be particularly friable, or the sutures have been drawn too tightly, and in consequence the threads have cut through, leaving a ragged edge. Great care should be exercised in every case to tie the knots gently, and with just the amount of force required to obtain a close approximation. This is particularly true when tying knots on a violently agitated heart, which is contracting spasmodically every few seconds. If the suture tears through, it may transform a simple longitudinal slit into a cruciform tear, which it will be impossible to approximate again by sutures. This is one of the most deplorable of calamities, because after the wound has been lacerated in this way by repeated attempts to suture it, there is very little prospect of closing the gap before the patient will bleed to death (Walker's case). It is possible that in such desperate straits the lacerated edges of the wound may be excised and the raw surfaces brought together with mattress sutures, as has been done with some degree of success in the experimental excisions of the heart in the lower animals. Usually from one to five interrupted sutures have been sufficient to seal the cardiac wounds.

Drainage of the Pericardium and Pleura.—As the most frequent cause of failure after cardiorrhaphy, infection of the pericardium or pleura, or of both together (septic pericardio-pleuritis), causing fully 45.4 per cent. of the deaths, according to Guibal's very careful study, it is evident that the efforts of the surgeons are at present very justly centered upon determining the best means of avoiding this fatal complication. In the peritoneal cavity the indications for and against drainage have been fairly well defined after a very long and warm wrangle; but the line of action is not so well drawn as to the pericardium and the pleura. In trying to solve this problem from statistical experience, Guibal (1905) reports that, in 66 cases of his collection, the suture of the pericardium and pleura *without* drainage has been done only 10 times; in 8 of these both the pericardium and pleura had been opened. Two of these cases were instances of pericardial injury without heart involvement, and 8 out of the 10 recovered: 5 without septic accidents, and 3 others after going through lesser infections. This small but remarkably good series of "closed" cases supports the contention of many writers who believe that the presence of the tampon or gauze drain is itself sufficient to cause pericarditis; that it frequently interferes with the escape of the secretions; favors stasis in the pericardium, and thus, ultimately, septic infection.

On the other hand, quite an important group of authorities, quoted by Tscherniachowski in his late memoir, unconditionally recommend drainage of the pericardium after cardiac suture as a preventive of septic pericarditis. Up to the present time the observations are not sufficient to justify a final judgment. Tscherniachowski, who drained in his case, is evidently much impressed with the merits of this procedure

and presents a series of tables which, numerically at least, would seem to show that drainage of the pericardium is the proper course to pursue, whereas the same practice is not the best for the pleura. He collected 90 cases, and in this group he found 42 cases in which the pericardium had been closed *without* drainage, with a mortality from pericarditis of 46.87 per cent. The pericardium was drained 23 times, with a mortality which he estimates at only 21.05 per cent. From the purely numerical point of view, these figures would show that a patient's chances of recovery are twice as great with drainage as without it. He believes that the majority of the wounds are already infected by the weapon, and also that better results would be obtained from drainage if the suggestion of Voinitch, to drain the pericardium by introducing a drain (preferably a tubular rubber drain, Rehn) to the depths of the sac at its internal inferior angle were carried out. With the majority of recent writers, he believes that the heart in all pericardial effusions is crowded by the fluid toward the anterior chest wall, and is very likely to obstruct a drainage opening unless the drain is placed in the most dependent portion of the sac and below the heart. In this Rehn, in his recent and most authoritative paper, fully coincides. While it is true that synechiæ or adhesions are constant after prolonged drainage, they also occur (as shown by Napalkow, Amerio, and Skawitz) even in simple punctured wounds which have not been operated upon.

The association of septic pleurisy with pericarditis after cardiac wounds is the most dangerous complication possible after cardiorrhaphy. Here again Tscherniachowski's statistics are interesting. He finds that in his 19 cases the pleura had escaped injury only in 7. It is, therefore, equally as important to guard against the pleural infection as the pericarditis. Here again we find two factions: those who drain the pleura and those who do not. Tscherniachowski found that, in 27 cases in which the pleura had been drained, 11 died, equal in mortality to 44 per cent.; after deducting 5 deaths not due to pleurisy, the septic mortality of the *undrained* cases is 30 per cent. In 27 cases in which the pleura was drained there were 15 deaths—55.55 per cent. mortality. By deducting 6 deaths not caused by pleurisy, the mortality was reduced in this group to 42.85 per cent. Statistically, therefore, a patient has a better chance for recovery after this injury with his pleura closed than open. Tscherniachowski believes that the relative rest of the pleura and lung, when injured as compared to the constant motion of the heart, gives the pleura a better chance to recuperate without drainage. Lenormant, on the other hand, in his analysis of 128 cases, finds that in 65 drained cases of either pericardium or pleura or both, 33.3 per cent. succumbed to septic pleuropericardial complications. In 23 cases which were not drained, 21.7 per cent. suffered from pleuropericardial complications which proved fatal in 17.4 per cent. As a purely statistical conclusion he, therefore, insists upon the hermetic closure of both pericardium and pleura in all *aseptic* cases. Rehn, basing his conclusion upon a collective study of 124 cases, concludes in favor of closing the pleura and aspirating the contained air when this

fails to be absorbed promptly. The chances of survival he thinks are about equal with or without pericardial drainage, and, as a general procedure, he advocates tubular drainage in the manner previously stated. In favor of closing the pleural wound and aspirating the air we quote Noetzel's recent experiments, which show that in animals, at least, the effects of pleural infection experimentally produced are always greatly aggravated by the coëxistence of pneumothorax. When the dead space left by the admission of air into the pleura is obliterated by the expansion of the lung, the chances of recovery are very much improved.

It is evident, from all this discussion, that the question of to drain or not to drain is not to be decided by statistics, and that each case must be judged by its individual merits. When there is good reason to believe that primary infection has been eliminated, it is safe to close the pleura and pericardium without drainage. When there is reason to doubt the asepsis, it will be safer to drain the pericardium in its most dependent portion and to close the pleura—unless it is quite certain that this cavity has also been contaminated. If it is decided that the pleura must be drained, this should be done in the most dependent position posteriorly, and a firm occlusive dressing should be applied which will allow the discharge to escape without admitting air, as this will perpetuate the pneumothorax—an especially undesirable condition under all circumstances.

Closure of the Wound.—If it is decided that the pericardium must be drained, the edges of the membrane should be attached by a few interrupted sutures to the deep pectoral aponeurosis, for reasons before given. If the case is aseptic and no drainage is required, it is important that the pericardium should not be hermetically sealed by a continued suture, as this will inevitably favor the retention and stagnation of the serum and exudates which will be poured into the sac as the result of traumatic reaction if the patient survives. A few interrupted sutures, leaving considerable interspaces between, will suffice to coapt the edges without interfering with the relief of pericardial tension. Interrupted sutures are also desirable in closing the remainder of the wound, the skin itself being brought into apposition with sterile adhesive strips or a few sutures, which will not interfere with the ready escape of the reactionary exudates and serous ooze.

Anesthesia.—In the majority of these cases a general anesthetic has been given. In 66 completed cardiorrhaphies Guibal finds that a general anesthetic was given 31 times; 20 times chloroform was used; ether 7 times; 4 times the anesthetic used was not specified; 16 times no anesthetic was given. It is evident that when the patients are in a collapsed or syncopal condition, or cyanosed by heart compression, the preliminary thoracotomy may be performed with slight, if any, anesthesia. If the patient is conscious, or if consciousness returns, ether should be given cautiously by the drop method. In a case of my own, operated upon in 1897, I traced out the outlines of the thoracic

trap-door flap by cocain infiltration; but it is a question, in my mind, whether that was necessary, as the patient seemed to show very little sensibility until the pericardium was opened. If the case is urgent, there is no time for an effective local or regional anesthesia by the massive infiltration method. Ether, given by the drop method on an open cone, is the preferable anesthetic. As a rule, very little will suffice to control the patient. If the heart's action should be interrupted and cease during the operation, direct cardiac massage rhythmically applied, as elsewhere described, should be resorted to.

Post-operative Treatment.—Shock and hemorrhage are the two great causes of the immediate mortality after these operations. After the suture of the heart wound has been successfully completed, the patients will be benefited by an intravenous injection of hot physiologic salt solution. The greater the hemorrhage and vascular depletion, the more is the intravenous solution indicated. Its administration must be watched with great care, for fear that the rapid introduction of a large quantity of fluid into the veins may cause an acute dilatation of the right auricle and ventricle from overdistention, as the heart muscle, in its weakened condition, is unable to contract effectively and empty itself rapidly enough to prevent venous stasis. If the patient is cyanotic and the pulse, instead of steadily improving, becomes irregular and imperceptible, instead of gaining in volume, strength, and regularity, as it should, it is evident that the saline injection is doing harm and must be stopped. Patients who show a disposition to duskiness, lividity, cyanosis, or capillary stasis and marbling of the skin should be propped up on pillows in order to keep the right heart from becoming overdistended with venous blood. In these conditions of profound shock the vasomotor control is lost and the influence of gravity is felt by the vascular system on the venous side, in a manner that never occurs when the vasomotor center is awake and thoroughly aroused to its functions. It is, therefore, a great error in all cases of evident venous stasis, when shock exists, to place the patient's head downward with a view to supplying blood to the medulla and nerve-centers. Patients under these circumstances do not die from cerebral anemia, as is usually believed, but die from cardiac paralysis due to an acute dilatation of an overdistended and weakened heart. If the patient is propped up in the Fowler position, as Crile has suggested, the pressure in the venæ cavæ and the right side of the heart being diminished by the effect of gravity in the semi-erect position, he will not only breathe better, but will be able to empty his heart if there is any contractile power left in the myocardium. Hypodermics of strychnin ($\frac{1}{60}$–$\frac{1}{30}$ gr.) with digitalin or digalen (Cloetta), ♏v–xvj, and small doses of morphin and atropin will do good, especially when combined with the cautious administration of black coffee, hot tea, champagne, and other forms of alcoholic stimulants of the kind that the patient is accustomed to. After the heart's action has been restored, saline solution may be continued by enema with coffee and laudanum in small doses as a stimulant as well as sedative. Overdistention of the

stomach with water or other drinks should be avoided on account of interference with the diaphragm and indirectly with the heart. Rectal enemata given slowly on the Murphy plan will do better. External warmth is, of course, always indicated as long as the temperature is subnormal and the peripheral circulation remains sluggish.

Statistical Conclusions and Causes of Mortality.—The combined statistics of Fischer and Loison (1869–96) show that in 629 cases of heart injuries recorded in the preoperative period, 84.8 per cent. died and 15.22 per cent. recovered, a mortality which is even less than it should be when we consider that needle punctures which yield 40 per cent. of recoveries without operation are included in this list. Salomoni, in 1906, tabulated 160 operations upon the heart, with 62 recoveries (43.83 per cent.). Wounds of the heart were sutured in 134 cases, with 49 recoveries (38.75 per cent.); in 11 cases the heart was exposed without suture, and 5 recovered (38.08 per cent.). Foreign bodies were removed in 5, with 5 recoveries (100 per cent.). In 10 cases both the diagnosis and issue were doubtful (30 per cent.). In 128 cases compiled by Lenormand (September, 1906) the mortality was 36.7 per cent.; in 124 cases, published by Rehn in April, 1907, there were 40 per cent. recoveries and 60 per cent. deaths. While the value of statistical conclusions must not be overrated, it may be safely concluded, with Salomoni, that heart wounds, far from being invariably fatal, give 3 chances in 4 for survival long enough to permit surgical intervention; 1 chance in 10 to heal spontaneously; and 1 in 2 to be cured by surgery. In the 49 recoveries analyzed by Rehn, the convalescence was uninterrupted and uneventful only in the minority of the cases. In the majority the post-operative course was either critical for days, stormy, or protracted on account of intervening complications. Traumatic pericarditis, serous effusions in the pleura requiring puncture, and emphysema (6 cases) and pulmonary infarcts were especially noted. Of Rehn's 75 fatal cases, 16 died on the table or within an hour after the operation; 17 died in a few hours from *shock and hemorrhage, i. e.,* 40 per cent.; 40 per cent. died of *infection* either in the pericardium or pleura or both. Therefore, of these 75 fatal cases, 84 per cent. succumbed from hemorrhage or infection. It is to be hoped that future improvements in the technic will protect patients better from these two great factors in the mortality. There is no doubt that, with improved methods of overcoming the evils of pneumothorax, not only will shock be diminished, but also the danger of infection, as Noetzel has pointed out. Pneumonia, embolism, cardiac thrombosis, valvular disorders created directly by injury to the valvular mechanism, myocarditis, and associate lesions of other organs,—peritonitis, etc.,—were the great causes of the mortality.[1]

[1] The latest tabulation of reported cases of cardiorrhaphy has been published by J. T. Vaughn (Jour. Amer. Med. Assoc., February 6, 1909). Including his own successful operation, he collected 150 cases, with a mortality of 65 per cent., showing that the mortality is still very high. He concludes that the evidence is against drainage of the pericardium and pleura. Sixteen gunshot wounds were operated upon with a mortality of 56 per cent., or 10 per cent. lower than other kinds of wounds treated by cardiorrhaphy. He reports 14 American cases with 6 recoveries.

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Foreign Bodies, Including Bullets.

Foreign Bodies in the Heart.—The tolerance of foreign bodies by the heart is, indeed, remarkable, when we consider the mobility of the organ, its delicate structure, and the dangers to which the patient is exposed by the coagulation of the blood and the migration of the clots. The foreign bodies most frequently found in the heart are needles, fragments of glass, of foils, bullets, etc.

Salomoni (1901) collected 97 reported cases of foreign bodies in the heart, 91 of which entered the heart through the chest walls, chiefly the precordial region, and 6 by the esophageal route. Of the 91, 40 recovered and 51 died. The other 6 all ended fatally.

The fate of foreign bodies in the heart, especially bullets, needles, fragments of knife-blades, etc., and the behavior of the heart in connection therewith have been experimentally studied by several recent observers, and the conclusions arrived at (which conform with those of clinical experience) may be briefly summed up as follows: (1) The tolerance of the heart, pericardium, and blood-vessels for projectiles, needles, and other foreign bodies is indisputable. (2) When bullets or other foreign bodies are retained in any of the organs, the results may be (*a*) immediate or prompt death, which is the usual occurance; (*b*) survival of several hours, days, or weeks, death resulting finally from secondary hemorrhage, septic complications, embolism, etc.; (*c*) complete tolerance with indefinite survival of the patients, the foreign body being only revealed at the post-mortem. (3) The fate of foreign bodies after entering the heart in case of survival is dependent largely upon their shape and size. Needle-shaped foreign bodies remain, as a rule, *in situ* or in the cavity involved, with the point buried in the wall. Thrombi usually form and organize around the foreign body when this lies exposed in the blood-stream. Migration of needles is favored by the heart movements, though it occurs less frequently than is usually taught. (4) Bullets and other foreign bodies, not needle shaped, are swept away, as a rule, out of the heart by the blood currents, immediately or shortly after entering one of the heart cavities, and are carried into the great vessels. Sometimes, though rarely, bullets will be dislodged from one cavity to another in a direction contrary to the blood-stream (ventricle to auricle, Haecker). The experimental demonstration of the tendency of the heart to eject out of its cavities any missiles or other movable bodies that may lie free in its chambers is fully confirmed by clinical experience, and should be borne in mind in all such cases on account of the danger of embolism which may ensue from the blocking of important arteries. On this point the clinical evidence furnished by Fayrer, Hamilton, Simmons, Randall, Morestin, and especially by H. Schloffer (1903), in his remarkable paper, is most interesting and conclusive. (5) On the other hand, bullets and other missiles may remain free in the heart cavities without causing any reflex functional or organic disturbances; hence extraction is not invariably required, and should be attempted only when called for by special symptoms.

On this point many illustrative cases could be gathered from the observations and classic papers of Geo. Fischer, Hermann Fischer, Loison, Salomoni, Riedinger, Socin, and Bergmann.

Note on Bullet Wounds.—Elten, not long ago, published a comparative statistical study of the mortality of gunshot wounds of the heart. In 25 cases of bullet wounds of the *right ventricle* one patient (4 per cent.) escaped with his life. Schloffer (1903) has compiled a table showing a list of 23 penetrating or perforating gunshot wounds, which either recovered or lived at least four days after the infliction of the injury. "Of the 23 cases above referred to, the right auricle was involved in 12, with a duration of life of 4 days, twice; 5 days, twice; 14 days, twice; two lived six weeks; some, many years; one recent case (Trendelenburg's) is still living."

In the statistical study of heart wounds treated by suture, we find that in Rehn's table of 124 cardiorrhaphies (including 1907), 15 were gunshot wounds, and of these 6 recovered (40 per cent.). It is remarkable that five attempts to remove bullets have ended in recovery.

Numerous experiments with modern small-bore military rifles, and the experience of recent wars and in civil practice, have impressed observers with the belief that small-caliber projectiles penetrating the heart while in *systole* result in smooth, tunneled wounds, while more extensive explosive effects occur from hydrodynamic action if the bullets strike the heart when it is full of blood—*i. e.*, in *diastole.*

On the battlefield, wounds of the heart and large blood-vessels at its root are probably almost immediately fatal. The majority of reported bullet wounds of the heart operated on in civil practice are inflicted with small pocket revolvers. It is possible that the low initial velocity, lack of explosive effect, and small size of missile, account for the fact that one or more cavities of the heart have been perforated without immediately fatal effect, and also for the number of cases in which the bullets have remained encysted in the heart walls, or found free in its cavities. That bullets so often fail to penetrate the heart is in part accounted for by Gaebel, who explains that the contracted heart of a healthy man is as rigid and hard as the biceps of an athlete, and offers a solid and unyielding surface almost as impenetrable as iron.

(6) Radioscopy, radiography, and the various special forms of apparatus devised for the accurate localization of projectiles and foreign bodies in the heart have proved of inestimable value, not only in diagnosis, but in the operative treatment of this class of cardiac injuries.

(7) With the present facilities for the diagnosis and localization of foreign bodies in the pericardium and the heart with improved methods of controlling hemorrhage from the heart itself, and with an improved general technic, the removal of foreign bodies from the pericardium and the heart should be unhesitatingly attempted whenever it is evident that they are causing serious disturbances or menacing life. A needle, accessible from without, should be promptly extracted. Should it be broken off and become inaccessible to external manipulations, its removal should be undertaken by a systematic, carefully planned thoracotomy. After the extraction of the needle or pointed body from the precordia, even if positive signs of heart injury are lacking, careful watch should be kept for signs of heart compression caused by traumatic hemopericardium. In such cases everything should be in readiness for a prompt decompressing pericardiotomy should such signs develop. Broken knife-blades, poniards, and other large weapons, visible and left projecting on the chest wall, or when felt subcutaneously, or when seen fluoroscopically, should never be removed without previous preparation for an instant aseptic pericardiotomy and cardiorrhaphy.

The following notable experiences on the extraction of bullets from the heart, reported by Podres, of Kharkoff (1898), and of Zoege v. Manteuffel, of Dorpat (1903), will suffice to illustrate the tolerance of the heart to foreign bodies and to surgical manipulations and the further possibilities of modern surgical technic.

A little girl, aged sixteen years, was accidentally shot with a revolver, the bullet

penetrating on the level with the fifth chondrosternal articulation. It was evident that the bullet had entered the chest and probably penetrated the heart. The shock and violent symptoms presented by the patient abated until about the fourth day, when a new exacerbation of symptoms, fever, cyanosis, dyspnea, and agitation, compelled Podrez to interfere. After a very extensive pericardiotomy he recognized a wound about 1 cm. in width in the right ventricle. The wound had not cicatrized, but was apparently closed simply by muscular contraction. Podrez attempted then to explore the tract of the wound in the heart with a probe, and then with a fine needle hoped to detect or feel the bullet. These measures failing, he made more than ten punctures in the vicinity of the wound in the ventricle, to see if he could locate the ball, but ineffectually. The operator then explored the entire pericardial sac and its various culs-de-sac with the finger, and, not finding the bullet, palpated the heart itself by holding it between the two hands and exercising sufficient pressure to permit of a fairly thorough exploration of the auricles and ventricles. Disappointed in all directions, the operator reluctantly abandoned further search for the missing bullet and tamponed the wound aseptically. The phenomena exhibited by the heart during these various manipulations and subsequently are very interestingly told, and were sufficiently alarming, but the patient survived in spite of many complications (arhythmia; edema of the lungs and of the lower extremities). Infection of the pericardium occurred, but after frequent irrigations the patient recovered. The wound in the heart was never sutured. Fluoroscopic examination subsequently showed distinctly that the bullet was in the heart, as it was displaced and moved rhythmically with it.

In agreeable contrast to the difficulties of the preceding case, we would quote the following remarkable and unique experience recorded by Zoege von Manteuffel, in which he extracted the projectile from the posterior wall of the right ventricle in the case of a woman of twenty-one years. After the pericardium had been opened the entrance orifice of the bullet was seen upon the right ventricle, 6 cm. from the apex, a blood-stream of 50 cm. in height spurting out with each diastole. This orifice was at once closed by a silk suture and the bleeding stopped. In order to locate the bullet the heart was cautiously raised a trifle, the pericardium being found intact. The bullet was felt in the posterior wall of the right ventricle, 1 cm. from the coronary artery. The heart was now lifted up by means of two fixation sutures, and the operator cut down upon the bullet, which he pressed out between the left index and thumb, so that it dropped into the pericardium. The second wound, which had bled but slightly, owing to the digital compression, was sutured, and the patient made a good recovery.

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Wounds of the Coronary Arteries.

To the question, can these arteries, so essential to the life of the heart itself, be ligated without fatal results, we find various replies. The older authors looked upon all injuries of the coronary vessels as necessarily and immediately fatal. Senac did not believe that they caused instant death, because hemorrhage from these vessels was not rapid or abundant.

Cohnheim (1881) taught that the ligation of one of the coronary arteries, which he believed were terminal arteries, induced immediate and fatal arrest of the heart. The contention of Michaelis (1893) and others, who deny the terminal nature of the coronary arteries because one of these can be forcibly injected from the other, has no weight—as W. T. Porter has shown—against the positive evidence of the complete failure of nutrition which follows closure of one end of the coronary circuit. Porter, in his exhaustive research (1903–06), in which over 100 ligations of the coronaries of dogs were performed, observed that cessation of the heart's action never occurred when the septal branch (arteria septi) alone was ligated; fatal arrest occurred only in 14 per cent. of the ligations of the right coronary; in 28 per cent. of the ligations of the descending branch of the left coronary, and with the greatest frequency, 63 per cent., if the circumflex (left coronary branch) was ligated. The prompt and fatal arrest of the heart's action preceded by a period of auriculoventricular incoördination which occurs so frequently after the ligation of the circumflex branch would suggest that a condition of "heart block" is induced by an acute ischemia of the bundle of His. The experimental evidence is conclusive in showing that the disturbance and fatal arrest of the heart after coronary ligation is due to ischemia and not to accidental injury to the myocardium. It is encouraging to know that in a considerable percentage of cases no immediately fatal or even secondary injury to the heart follows the occlusion of one of the larger branches of the coronary. It is also evident that the resulting disturbances are less dangerous, as these vessels are ligated at a distance from their origin. The failure of the ligature to cause either immediate or secondary injury to the heart in many of the dogs experimented upon, and the non-occurrence of myocardial degeneration in cases of pathological occlusion of these vessels in the human subject, can only be accounted for by the establishment of a collateral circulation or by the existence of anomalous branches of communication between the two coronary systems.

Capellen (1896) ligated the left anterior descending coronary in the human subject for the first time, and though his patient died, the

end was not brought about by the effect of the ligature, but by a septic pericarditis. Pagenstecher found the left coronary cut across 5 cm. above the apex. He ligated both ends of the vessel, and, though his patient died five days after from purulent pleuropericarditis, the heart did not appear to suffer from the effects of the coronary ligature.

In spite of the comparatively small size of the coronary artery, bleeding from this source is quite sufficient to cause death from surgical anemia, apart from heart compression. In Lamotte's case there was a double hemothorax which filled up the chest when death came. Capellen's patient had 15 grams of blood in his pleura, besides a very large hemopericardium. An enormous hemopericardium was found by Peek Richards (1891), at the autopsy of an insane patient, caused by the pricking of one of the coronaries with the fragment of a needle introduced with suicidal intent. And so we find other cases recorded in the literature of the preoperative period. Larry, Perry, Clark, Beckert, Parisot, Turner, Klihm, and others have recorded autopsies in which the wounds of these vessels had healed completely and had been followed by long survivals, death having come from entirely different causes than heart injury. Turner's patient died of purulent pleuropericarditis four months after a stab wound of the heart, Klihm's, from the effect of complicating spinal lesions two months after a gunshot wound of the heart. In both of these the anterior descending branch of the left coronary was involved. In both the autopsy demonstrated that the coronary wounds had healed. In view of these facts we would conclude that the coronary vessels should be ligated unhesitatingly whenever they are found bleeding in the course of any operation on the heart or pericardium, the opinion of some authorities to the contrary notwithstanding.

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Cardiac Stimulation for Suspended Animation by Various Procedures.

Experiments on the mammalian heart and clinical observations on the human heart show that its functional activity may be restored by at least six different modes of treatment: stimulation by—(1) *Handling*, touching (Panum, Bloch); (2) *needling* (Watson, 1887); (3) *aspiration* of the heart cavities to relieve venous repletion and chloroform syncope (Le Fort, Weynich, Westbrook, 1882); Dana, Mills (1887); Leuf (1885); Pepper (1888–89); aspiration for air-embolism Senn (1885); (4) direct cardiac electrization (Mauclaire); (5) direct arterial infusion through the carotid toward the heart, to fill the coronary circle with Lock's solution (Spina, 1906) or with defibromated peptone and piridin blood transfusion (Zeller, 1908);

(6) heart massage; by combining cardiac massage with arterial saline infusion and adrenalin (Crile, 1908). Some of these methods have been discarded as too dangerous and uncertain to deserve a place in surgical therapeutics; others have been discussed sufficiently in other parts of this work (see Hemorrhage), and we shall now confine our attention in this section to massage.

Massage.—Peripheral compression, or massage of the heart, with the object of establishing a sort of artificial circulation and arouse the heart to contraction after its movements appear to be suspended by accidental causes, originated with Schiff, the physiologist (1874), and remained, until quite recently, strictly confined to laboratory practice on the lower animals.

Massage acts on the heart by: (1) Emptying mechanically the distended cardiac chambers; (2) creating an artificial circulation; (3) keeping up the nutrition of the myocardium through the coronary vessels; (4) artificially pumping blood to the brain and correcting the circulation of the medulla and central organs of the nervous system; (5) stimulating the reserve energy of the cardiac muscle.

Massage can accomplish no good after—(1) Coagulation of the blood in the heart has taken place, and (2) the myocardium itself has lost all contractility by postmortem coagulation; (3) whenever the respiration fails or the central automatic reflex centers of the medulla are permanently damaged.

In order to apply massage directly, the hand of the operator can reach the heart by one of three routes: (1) The sternocostal or transthoracic route (Neihaus, 1880; Tuffier, 1898), by which we may reach the heart by simple intercostal incision—thoracotomy; (2) the abdomino-transdiaphragmatic route (Mauclaire, 1902), in which the heart is reached by an incision through the diaphragm after laparotomy; (3) the abdomino-subdiaphragmatic route (W. A. Lane, 1902), and its extraperitoneal modification, proposed by Tomaselli (1907). The subdiaphragmatic method, which accomplishes all that can be expected of cardiac massage without any of the risks of bad after-effects of the other methods, should be adopted as the method of election and preferred, even when syncope occurs in the course of operations outside of the peritoneal area.

Technic.—By an epigastric incision the hand grasps the heart through the relaxed thin diaphragm, the organ being held as nearly above the apex as possible, so as to compress the ventricles rhythmically, 20 to 40 times a minute, between the thumb and finger. In applying cardiac massage it is evident that the earlier it is done after the apparent cessation of the circulation the better. In some cases the response of the heart is immediate; in some no contractions have been felt until five minutes have elapsed (Sencert); six to eight minutes (Lenormant); and not until fifteen minutes in others (Prus, Sick). In 25 cases reported by Lenormant the sternocostal route was adopted 16 times, with 12 total failures (75 per cent.), 3 temporary recoveries (18.8 per cent.), and one permanent recovery (Igelsrud in Keen's paper), or 6.2 per cent.

In a summary of 39 cases reported by Ricketts the total number of cases in which the heart-beat was permanently reëstablished was 12 (34 per cent.). The ages were given in 22 cases (extremes: oldest, sixty-five years, recovered; youngest, seven years, died). The time before the heart function was reëstablished was one to sixty minutes; the greatest length of time of cessation of heart-beat to be reëstablished permanently was twenty minutes.

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SURGERY OF THE ARTERIES.

DISEASES AND INJURIES OF THE ARTERIES.

Anatomic, Physiologic, and Pathologic Peculiarities of Surgical Interest.—A preliminary knowledge of the chief structural and functional peculiarities of the arteries is essential to a proper appreciation of their behavior when injured, and of their reactions when diseased.

Arteries are classically described as consisting of three coats: an internal (intima), a middle (media), and an external (adventitia). The intima is in immediate contact with the blood and is formed by an exceedingly thin, transparent layer of endothelial cells of an irregular or fusiform, squamous type, inclosing oval nuclei, the long axis of which, as well as of the cell, lies parallel to the long axis of the artery. The endothelium has no direct blood-supply except the blood-stream, with which it is in direct contact. The endothelial cells have an enormous power of reproduction, which is promptly brought into activity by mechanical or chemical irritants. This was first appreciated by J. F. D. Jones (1805), who showed in his experiments that, on account of its regenerative properties, it was only necessary to injure the intima in order successfully to obliterate the vessel after its ligature.

His was the first to substitute the word *endothelium* for *epithelium*, which was applied by his predecessors to the lining membrane of the vascular and lymphatic system. Scarpa, before him, called attention to the histologic as well as germinal relation which united the lining membrane of the entire vascular system with that of the lymphatic tracts, the serous cavities, and the synovial sacs of joints and bursæ. Zeigler subsequently compared the intimal proliferation after a ligature to the plastic inflammation of a serous membrane.

Hence, the surgical importance of the concept of the "unity of the endothelia"—which is as true physiologically and pathologically as it is in the histologic sense. The principle of "*intima* to *intima*" signifies just as much in the plastic surgery of the blood-vessels as that of "*serosa* to *serosa*" to the abdominal surgeon. It means that endothelial surfaces when brought in contact under abnormal conditions of irritation or trauma quickly unite and fuse with each other as the result of rapid cell proliferation. It is in consequence of a better appreciation of the rapid and enormous reproductive power of the vascular endothelium that the great progress in vascular surgery, the modern ligature, the suture, transplantation and substitution of vessels, obliteration of aneurismal cavities by intravascular suture, and transplantation of organs, has been accomplished. The chief function of the normal endothelium is to preserve the continuity of the blood-stream by preventing coagulation, which immediately occurs in a blood-vessel the moment its endothelial lining is damaged by injury

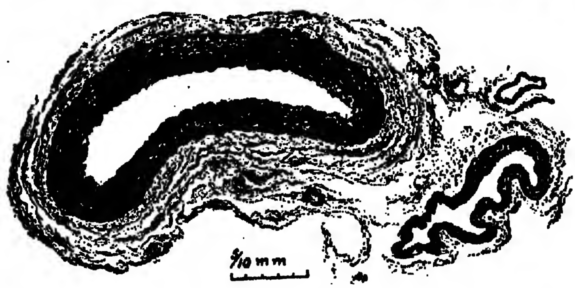

FIG. 26.—NORMAL RADIAL ARTERY AND VEIN (× 20). (Meigs.)
From a negro woman twenty-five years old who died of meningitis. The artery is to the left, and it is as nearly normal as any of the arteries of persons who have died of disease. The intima is always as thick as it is here represented. The vein is the thin-walled vessel to the right.

or disease. Outside of the endothelial layer lies a thin loose connective-tissue stratum which connects the intima with the internal elastic lamina, the fenestrated membrane of Henle, which is composed of a layer of longitudinal fibers running parallel with the long axis of the artery.

The *middle tunic* is formed of two constituent elements: (1) A muscular layer of unstriated fibers or muscle-cells (the muscularis) and (2) an *external* elastic lamina which defines the boundary between the media and the adventitia. H. Dürck (1907), by adopting Weigert's new nerve stains, has shown that the subendothelial elastic lamina and the external elastic of the media are connected by tense radiating elastic fibers between which the muscular elements of the artery are interposed. The elastic fibers act as physiologic antagonists of the circular muscular layer. In the rhythmic play between contraction and dilatation which is constantly going on in the peripheral vessels, vasoconstriction, which is a vital act, is followed immediately by the recoil of the elastic membrane, which brings the vessel back to its dilated resting position. As we ascend from the very small to the higher peripheral and visceral arteries the number of muscular fibers become so

great that in cross-section it forms a well-marked ring of non-striated muscle with comparatively little connective tissue. In the arteries of the first magnitude the elastic tissue almost entirely replaces the muscular layer of the media. The middle tunic is composed of elements which are easily injured and degenerated by diseased conditions, and have relatively little power of regeneration, especially when compared with the intima or adventitia. Repair of these elements is more often accomplished by the substitution of fibrous cicatricial tissue for the lost muscular and elastic elements. The media receives its nourishment from the *vasa vasorum*, which penetrate to the internal elastic lamina after ramifying in the adventitia.

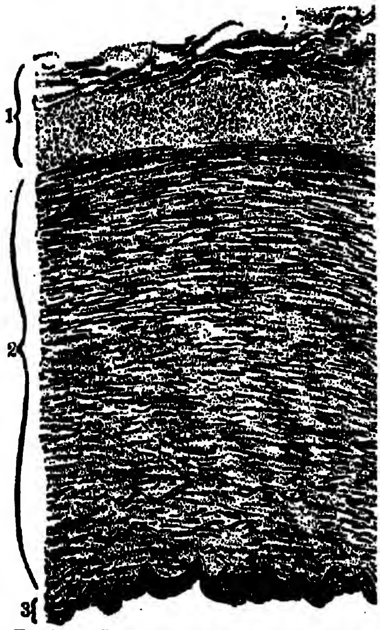

FIG. 27.—SECTION OF THE BRACHIAL ARTERY. 1, Outer coat (thick); 2, media; 3, intima. (Ballance and Edmunds.)

It is the elasticity of the arteries which gives them their firmness, their rotundity, and their mobility; it is also this quality which keeps them open when empty and prevents their collapsing when divided in cross-sections. It is also the brittleness of the elastic lamellæ which causes the intima and media to break and curl up inside of the adventitia when an artery is crushed with a ligature or with clamps. It is also this elastic retraction, combined with coincident contraction of the muscular elements, that closes the mouth of a divided artery and thus favors natural hemostasis.

The *adventitia* or external tunic consists (in the arteries of medium size) of bundles of white fibrillar connective tissue containing some elastic fibers. While looser in texture, and apparently of less strength, the adventitia is nevertheless more resistant than either of the other coats. It alone preserves the continuity of the artery after all the other tunics have been crushed or completely ruptured by tying, stretching, or twisting. The adventitia also acts as a protecting wall which stoutly resists the invasion of outside microörganisms. It also serves as a bed for the distribution of the vasa vasorum and the nerve plexuses (vasomotor nerves), preparatory to their final distribution into the muscular layers of the media. The vasa vasorum are furnished by the nearest branches of the parent trunk or of adjoining arteries, and not by the main body of the artery, the vessels differing from the nerves in their distribution, which is limited in the artery to the media and not to the intima.

The extent to which the arteries may be stretched has not been

accurately estimated. Veins may be stretched 50 per cent. without passing the limit of their elasticity, *i. e.*, when the vein is freed from its adhesions to surrounding tissues, 50 per cent. of the distance may be removed and still the veins possess sufficient elasticity to be approximated (Murphy). Murphy, Carrel, Hoepfner, Stich, and others have demonstrated that relatively large sections of the arteries could be removed and the ends approximated by suture without difficulty. The internal pressure which a vessel will withstand is very much greater than the normal arterial pressure to which it is subjected, showing that in the progress of surgical repair a wall much more feeble than the normal wall of the vessel is sufficient to hold the blood in control. Volkmann found that the carotid of sheep would rupture only when fourteen times the normal pressure was put upon it. The carotid of a dog withstands fifty times the normal blood-pressure; the jugular vein one-half of this (Gréhant, Quinquaud). It may be deduced from this that there is little danger of aneurism at the point of union of a sutured artery, even if the walls are somewhat weaker than normal (Murphy). Abundant clinical testimony with arterial suture fully confirms this statement.

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Acute Arteritis.—Acute arteritis is a general designation which includes a variety of strikingly different types of acute arterial disease. From the purely histologic point of view, arterial inflammations may be subdivided into: (1) Periarteritis; (2) mesarteritis; (3) endarteritis, according to the primary or chief seat of the lesion in the adventitia, media, or intima. There is no sharply defined limitation of the inflammatory process to either of these coats, as suggested by these designations, but the primary seat of the disease is thereby emphasized. The word *panarteritis* is used to distinguish those forms of acute arteritis in which the entire vascular wall is involved, as is most frequently observed in the localized forms of arterial infection of pyogenic origin. An etiologic distinction which can be recognized clinically should be made between: (1) The acute types of arterial inflammation, which result from the presence of living (especially pyogenic) organisms in the circulation and their toxins; and (2) those produced by toxins and other products of bacterial activity elaborated in distal parts of the organism. In the last group a toxemia is produced in which the bacterial poisons circulating in the blood, such as barium chlorid, alcohol, adrenalin, etc., act on the blood-vessels in the manner of chemical poi-

sons. We should bear in mind that in either of these pathogenic groups the traumatism and other influences, must be considered in determining localizations in definite areas of the circulation; the tendency in the first group being notably toward virulent localization of destructive intensity in small, definite areas; while that of the second group is toward the production of widely diffused or disseminated processes.

I. Pyogenic or Purulent Arteritis.—The first group may be subdivided into—(*a*) the *perivasal* and (*b*) the *endovasal* infections, the infection in both groups recognizing a staphylococcal and streptococcal or mixed origin in most cases. The perivascular type is initiated in the adventitia, constituting the clinical type known as "suppurative" or "ulcerative periarteritis," "ulceration" or "erosion" of arteries. It occurs most typically when an artery lies exposed in an abscess cavity, bathed in virulent phlegmonous pus. This occurrence is not rare in the neck (carotid and peritonsillar), axillary, iliac, inguinal, or popliteal regions, where the anatomic conditions, as well as the frequency of deep infections, predispose to perivascular suppuration. While arteries are frequently brought in contact with pus, suppurative periarteritis with ulceration and rupture of the artery into the abscess cavity is not a frequent occurrence, because arteries are nourished by their own blood-vessels, the vasa vasorum, which are independent of the main trunks themselves, and they are, therefore, able to offer greater resistance to the encroachment of outside traumatism and bacterial invasion than the surrounding tissue. It is not unusual for a vessel to remain apparently intact in a bed of necrotic or suppurating tissue. However, this immunity or resistance to infection is limited and is very materially affected by the extent of the injury and the virulence of the infection.

Secondary hemorrhage, the formidable specter that haunted the surgeon of the preantiseptic period, is caused by a purulent periarteritis in which the bacteria are carried to the lumen of the vessel by the septic ligature. Here all the conditions favorable for infection are prepared by the detachment of the vessel from its bed and the crushing effect of the ligature upon the arterial tunics, especially as the ligature was then always applied with sufficient force to lacerate the intima and media. Then the only protection against hemorrhage was the presence of an obturating septic clot, which often disintegrated into a puriform mass as the local infection progressed. That secondary hemorrhage did not occur invariably under these circumstances, especially when the large arteries were ligated, is surprising. At present, the dangers of hemorrhage from septic or purulent periarteritis need scarcely be taken into account in operative work.

In the violent forms of purulent periarteritis the entire thickness of the arterial wall may become sphacelated or gangrenous (arterionecrosis). When interstitial suppuration occurs, the arterial wall is undermined and ulceration takes place. The elastic lamellæ for a time will provide a protecting wall which, yielding gradually, forms with the intima a hernia-like aneurismal dilatation, "the erosion

aneurisms of Eppinger." These always terminate in hemorrhage which has no tendency to be arrested spontaneously. They are not infrequent in the lungs as the result of tuberculous arteritis, or in the brain as the result of the breakdown of gummatous infiltrations of the adventitia. In addition to these erosion hemorrhages which occur in the lungs, cases are reported of erosion from the same cause in cold or migrating abscesses in Pott's disease. Monod, who studied these arterial ulcerations in 1882, tabulated 51 observations from the literature. In 37 cases the hemorrhage was caused by pus infection in abscess cavities. In addition, erosion from mechanical irritation and compression from sequestra in fractures and osteomyelitic foci, prolonged contact with rigid drainage-tubes (Bouilly), are quoted. The vertebral artery has been ulcerated in cervical Pott's disease (Regnier). Hessler collected 19 cases of hemorrhage of the internal carotid resulting from caries of the temporal bones and carotid canal. In an exhaustive study of the hemorrhages resulting from erosion of the carotid and its branches in peritonsillar abscesses, Lebram (1906) reports 25 cases, including 2 of his own. This grave complication is not as rare as it appears in the literature. Of these, 9 recovered in which the common carotid was ligated, and 15 died. Lebram has also collected 23 cases of erosion hemorrhage from purulent infiltration of the lateral sinus, almost all occurring as a result of scarlatinal otitis and mastoid infection.

Hoffman (1906) has especially investigated the erosion hemorrhages which occur in appendicular abscesses. After quoting the statistics of Hemmig, Hagen, Bode, and others, he states his own statistics, which show four hemorrhages with 3 deaths in 450 cases and 400 operations. When an artery has been eroded in an abscess cavity, the weakened arterial coats yield as a result of the sudden removal of pressure, which, prior to the opening of the abscess, counterbalanced the intravascular tension. Sometimes, in abscesses of low tension, with well-defined walls, the artery will rupture into the cavity and simulate an infected diffuse aneurism or pulsating hematoma. Sometimes, after an abscess has been opened and drained, a few repeated hemorrhages, "the warning hemorrhages of Pirogoff," precede the final and often fatal gush. It is important to protect all vessels, arteries as well as veins, exposed to infection in suppurating cavities by not opening, incising, or otherwise disturbing the aponeurotic sheath, which is their normal barrier to infection. It is also important to support the artery by well-adjusted antiseptic packs or tampons, when the surrounding tissues have been destroyed, so that the tendency to yield to intravascular pressure may, in some measure, be obviated. Impending perforation of the arterial wall is often announced by the formation of an embolic or a thrombotic aneurism at the seat of the perforation, the thrombosis giving rise to all the signs of ischemia, stasis, and gangrene in the peripheral parts.

II. **Localized Septic Endarteritis of Embolic (Pyemic) Origin.**—This form of acute arteritis begins as an endovasal process, and is always the result of the lodgment of an infected embolus or propa-

gated thrombus in an artery. It differs from periarteritis by the sudden and abrupt development of disturbances in the peripheral circulation as the result of initial thrombotic manifestation. In the periarteritis, thrombus formation is a terminal feature of the process, the protective thrombus being washed away by the hemorrhage following the rupture of the artery. The local effects of these mycotic or infected emboli may be stated as: (1) Septic suppurative thrombo-arteritis beginning in the endothelium; (2) secondary panarteritis; (3) metastatic abscess, when the smaller vessels are involved; (4) degeneration of the vessel-wall, followed by ulceration, erosion, necrosis; (5) aneurismal dilatation from weakening of the vessel-wall at the point of obstruction (mycotic embolic aneurism); (6) increased area of coagulation in the blocked vessel by propagation of the thrombus along its infected walls; (7) gangrene of the peripheral parts supplied by the obstructed artery, unless the collateral circulation is sufficient to compensate for the obstruction. An infective embolus presupposes an infected thrombus somewhere as the source, from which the embolus is detached and by which the primary infection is disseminated. If it be pyogenic in character, as is often the case, a metastatic abscess is developed at the point of embolic obstruction, and the condition of pyemia is established. Arterial emboli are formed (more often than from any other cause) in the valves of the heart or in the aorta, on surfaces roughened by previous disease of the endocardium or in atheromatous patches in the aorta. Arterial embolism has been noted in 35 per cent. of cases of heart disease (Günsburg, Eichhorst). The order of frequency of arterial embolism is given by Welch as follows: Pulmonary, renal, splenic, cerebral, iliac, and other arteries of the lower extremity; celiac axis with hepatic and gastric branches; central artery of the retina, superior mesenteric, inferior mesenteric; abdominal aorta and coronary arteries of the heart. It is very probable that embolism of the small arteries of the lower extremities would come next to the pulmonary in the order of frequency, but the signs and symptoms attending this event may be so unimportant as to be overlooked or misinterpreted (A. S. Warthin). It is evident that the relation of the endarteritis is a purely secondary one, the artery being infected by the embolus. From this viewpoint, the clinical manifestations of embolic endarteritis are practically the same as those of thrombo-arteritis when this occurs in the course of the infectious diseases. In patients suffering with general staphylococcal and streptococcal, typhoidal, rheumatic, gonococcal, influenzal, and other general infections, the septicemic state is often complicated by ulcerative endocarditis. The risk of embolism is then greatly increased. In the peripheral arteries it will be announced abruptly by local intense pain in the limbs, with diminished function and diminished or absent pulsation beyond the line of obstruction. When the thrombosed artery is superficially situated, it can be palpated as a hard cord, extremely tender to the touch. If the obstruction is complete, the pulse is lost altogether in the distal parts, the limb becomes edematous, the surface cold, anesthetic or paresthetic. Stasis occurs in the

capillary circulation; irregularly outlined, pale bluish spots form in the dependent parts, and even spots of an ecchymotic or purpuric character make their appearance in the skin. The further course will depend upon the virulence of the embolic infection and upon the establishment of the collateral circulation. When the collateral circulation fails, gangrene follows. If the collateral circulation develops, an impending gangrene will be averted. If the embolus is infected with pyogenic organisms, panarteritis will follow, with the formation of an abscess, and ultimately (in the larger arteries) a secondary hemorrhage as the result of perforation.

FIG. 28.—TRANSVERSE SECTION OF THE POPLITEAL ARTERY, SHOWING THROMBO-ENDARTERITIS (NON-PYOGENIC; ×8). (Ballance and Edmunds.)

From a man aged thirty-five years who had gangrene of the right foot. There was no visceral disease and the case was apparently an example of the endarteritis proliferans of Friedländer. In the section the wavy fenestrated membrane of Henle can be seen on close inspection. Internal to it the thickened intima is represented black. A clot nearly fills the vessel. The darker area of the clot is permeated by cells derived from the endothelium, which have partly transformed it into connective tissue. The narrow white spaces are all that is left of the lumen of the vessel; here alone the circulation continued.

III. **Acute non-pyogenic arteritis,** as a primary process (not secondary to embolism), may occur from traumatic, toxemic, and non-pyogenic bacterial infections. This group differs etiologically and histologically from the preceding in the fact that the structural changes in the arterial wall do not lead to progressive ulceration or purulent infiltration. As usually observed, acute non-pyogenic endarteritis is a widely diffused process, affecting large areas of the vascular system at the same time, usually in the lower extremities. The intima is the first and chief sufferer. The essential histologic difference which separates this group from the pyogenic is that, instead of the enormous leukocytic infiltration of the arterial coats, there is, in addition to thrombosis, a tendency to hyperplasia and endothelial proliferation. Sometimes the arteritis is started in the media by the toxic blood brought to it by the vasa vasorum, causing a mesarteritis. Acute non-purulent arteritis may occur in every general infection in which

toxemia occurs, but is most frequent in those of long duration. In these, a lingering, wasting fever causes a sluggish peripheral circulation, due to an exhausted vasomotor center and a weakened degenerate heart. Other conditions favorable to the stagnation of blood in the capillary circulation occur in the peripheral parts of the extremities. These, with hemolytic processes, which favor intravascular coagulation, all combine to inaugurate the thrombo-arteritic process. It is not surprising, therefore, that typhoid and typhus fevers should stand first in the list of the thrombogenic diseases, followed by the exanthemata (small-pox, scarlatina, measles), acute articular rheumatism, pneumonia, and general pneumococcal infections, diphtheria, gonorrhea, and the chronic malarial infections. The influence of syphilis in exciting endarteritis is particularly malignant, but it is considered apart from this group because it gives rise to special types of arteritis, which, regardless of their histologic peculiarities, prefer certain vascular territories in the brain, spinal cord, the aorta, and the large central arteries, where the disease is followed by the gravest consequences, such as paralyses from thrombosis of the branches of the circle of Willis, and by aortic aneurisms, all of which especially concern the internist. In summing up the etiology of this group of arterial lesions, we would state that any agency capable of exciting the characteristic tissue reactions of an endocarditis is likewise capable of injuring the endothelium and other coats of the blood-vessels in the manner above described.

In *the clinical study* of the acute forms of arteritis in general the peripheral and the visceral forms of the disease must be considered from the surgical viewpoint, and, in this regard, thrombo-arteritis of the extremities, more especially of the lower limbs, claims the greatest attention. Of the visceral and internal thrombo-arterial localizations, the aortic, mesenteric, renal, splenic, and hepatic areas also claim special attention because they are associated with secondary obstructive disorders, infarcts, visceral abscesses, and gangrenes, which follow the occlusion of the terminal and main arteries. An embolus, lodging at the bifurcation of the abdominal aorta, may be followed by gangrene of the lower limbs; mesenteric thrombosis and embolism lead to gangrene of the intestines, and metastatic infarcts in the kindeys, liver, and spleen frequently give rise to surgical conditions demanding operative interference.

Chronic Arteritis—Arteriosclerosis.—This is the largest group of the arterial diseases. It is properly claimed by the internist as his special province, but is, nevertheless, of great and growing importance to the surgeon, who should be familiar not only with its local obstructive manifestations, as they are observed in the extremities, but also the general constitutional effects of the arteriosclerotic processes in their relation to general surgical practice, *i. e.*, their influence in diminishing the resistance of the individual as a whole, interfering with the nutrition of the tissues and with their reaction to trauma, shock, infection, hemorrhage, and to the toxic effect of general anesthetics,

etc. The pernicious effect of degenerative changes in the blood-vessels is also felt by the general metabolism of the arteriosclerotic subject which makes him more liable to auto-intoxications and to other conditions that unfit him for the work of the surgeon.

We are now especially interested in the local effects of the arteriosclerotic process which the surgeon is called to see only in its advanced stages, when the arteries are palpable, thick, and hard, and their lumen is contracted; when obstruction in the peripheral arteries has actually taken place or is threatened..

In the study of this most important vascular disease it is well that the student should know at the outset that the numerous designations given by pathologists to this condition, in the course of its historic evolution, such as "chronic arteritis," "atheroma," "arteriocapillary fibrosis," "obliterative endarteritis," "endarteritis chronica diffusa," "endarteritis nodosa or conscripta diffusa," "angiosclerosis," "atherosclerosis," "arteritis ulcerosa seu verucosa," all apply to the protean phases of one and the same process, more or less modified by the duration of the disease, the regions, and anatomic conditions in which it occurs, as well as its specific causes, yet all referring to the same fundamental processes, the progressive hardening of the arteries. It is this condition which justifies the name of *arteriosclerosis*, first given to it by Lobstein in 1835, and which has clung to the nosology with greater tenacity than all the others.

While this process may involve only a sectional area of the arterial system, it more often affects the entire vascular system, including the arteries, veins, and perivascular tissues and organs in a generalized diffuse sclerogenic process. Arteriosclerosis must be regarded as a complex disease which manifests itself in many different types, all of which may appear in the same individual and as the effect of the pathogenic operations of one common cause. Thus the syphilitic poison may give rise to all the known types of arteriosclerosis in the same individual. In some instances a single coat of a vessel is affected by fibrous or other allied changes; in others, several tunics of the same artery are involved. Hence, we may have two or more processes inextricably mixed in a progressive disease of the arterial coats. The type of the disease that is most frequent in the extremities is what Klotz, Adami, and others have described as the "Moenckeberg type," which is recognized by the clinician in the hard and tortuous radials and temporals. "In this type the disease begins in the muscle-cells of the media, and the media alone is damaged primarily. The intima and adventitia are not essentially involved in the process, though occasionally a secondary intimal thickening accompanies the medial degeneration. The main changes in the media are a fatty degeneration of the muscular and later of the elastic fibers, both of which become calcified and rigid. It is through these calcareous plaques in the media that the beaded character is given to the radials." On the other hand, the "Jores type" of arteriosclerosis is characterized by primary proliferation of the intima and secondary involvement of the subepithelial con-

nective tissue, leading to atheroma and obliterative changes. Wherever the process begins, or whichever type it may assume in the incipiency, it always tends to the same effect—the loss of elasticity in the vessel coats with progressive tendency to rigidity, thickening, elongation, and contraction of the vessel lumen. In the great arterial trunks, aorta and primary branches, the loss of elasticity leads to dilatation and aneurismal formation.

Clinically, the affected arteries are recognized as hard, roughened, tortuous vessels, readily palpated under the skin as they follow a serpentine course visible to the eye in many regions (wrists, temple, neck). This is most readily recognized in aged persons (senile type). On account of their hardness and brittleness, the arteries are ligated with difficulty or crushed and torn when held in forceps. In a remark-

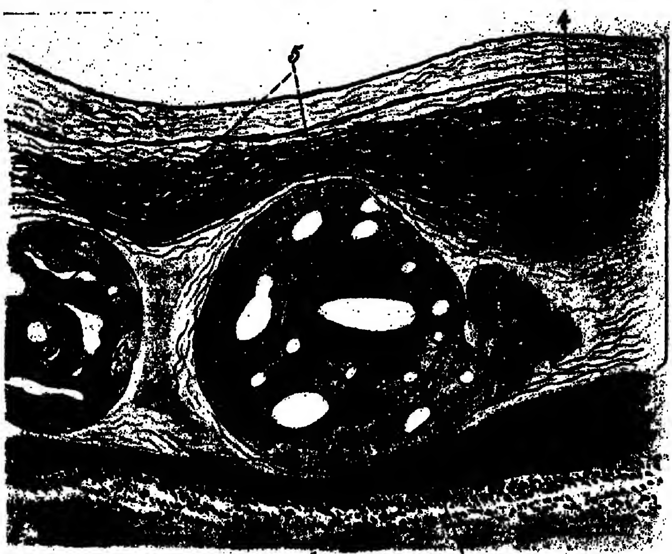

Fig. 29.—Arteriosclerosis of the Femoral Artery (× 55). (Dürck.)
1, Adventitia; 2, compressed and atrophied media; 3, greatly thickened intima; at 4, sclerotic, fibrous tissue, non-cellular; at 5, scales of lime salts containing spaces filled with a fatty detritus.

able case of aortic abdominal aneurism reported by Lozano (Saragossa) in 1905, when this surgeon attempted to operate by the intrasaccular method (Matas), the aorta crushed and crumbled under the pressure of the elastic forceps used to control the circulation of the vessel, so that the fragments of chalky matter formed in the sclerotic artery, tore through the vessel-wall, causing hemorrhage which could not be controlled except by leaving a forceps on the artery at a higher point. When calcareous degeneration has occurred, it appears distinctly in x-ray pictures as a well-outlined shadow (Fig. 30). Levy-Dorn claims that even the coronary arteries of the heart when sclerosed can be demonstrated in the radiographs.

Clifford Allbutt divides arteriosclerosis into three great clinical types: (1) The *senile*, not necessarily associated with increased arterial

tension; (2) the *mechanical*, resulting from long-continued hypertension of the arteries of whatever origin; (3) the *toxic*, in which hypertension occurs as a rule (nephritis). The general fact to be remembered is that the process, when generalized, almost invariably begins as a functional overstrain of the artery. Added to this general cause we must consider as determining or associate etiologic factors all the vascular poisons, alcohol, tobacco, ergot, lead, mercury, and phosphorus; the infectious diseases, especially syphilis, typhoid, tuberculosis, leprosy,

Fig. 30.—Atheromatous Arteries in a Man of Sixty-one Shown by the *x*-Rays. (Case of Keen, skiagraphed by Manges, Jefferson Hospital.)

a, Brachial artery; *b*, bifurcation; *c*, radial, *d*, ulnar arteries. There was a posterior dislocation of the elbow, which had been reduced, and a fracture of the head of the radius, which shows.

the chronic disorders of metabolism, with their autogenic poisons, many which are not yet known and in which we provisionally included gout, diabetes, arthritis deformans, violent physical exertion with acute dilatation of the heart, disorders of the central and peripheral nervous system which affect the trophic control of the blood-vessels (tabes, syringomyelia, neuritis), overeating and drinking, worry and psychic wear and tear, extremes of temperature, especially cold.

The **effects** of arteriosclerosis are: (1) Disturbances in the general circulation and the function of the individual organs, due to the diminished

elasticity and stenosis of the vessels, most marked when the veins are simultaneously sclerosed (varices); (2) ischemia of the peripheral parts below the obstructed arteries (in the terminal stages, when the lumen is obliterated by proliferation of the intima or the formation of a thrombus). When these conditions are combined with impaired, dilated heart action and sclerotic collaterals, mortification, usually of the dry, mummified type, takes place in the dependent parts, as, for example, senile gangrene of the toes and fingers, followed often by embolic gangrene of the entire limb; (3) rupture of blood-vessels, especially of the central cerebral arteries, leading to apoplexy; (4) miliary aneurisms in the cerebral and visceral arteries (splenic, mesenteric, renal, etc.); (5) aneurisms in general, but more especially of the aorta and great central arteries of the fusiform and sacculated types; (6) thrombosis.

The very interesting experimental data which have accumulated since 1903, when Josué first succeeded in producing sclerotic and degenerative lesions of this type in the aorta of rabbits, and since confirmed by a great number of investigators, have not yet succeeded in elucidating the problem of the etiology of arteriosclerosis in all its phases. These investigations, however, have distinctly contributed to a clearer and better defined conception of the arteriosclerotic process. It has been denied that the experimental lesions produced in rabbits by adrenalin, digalen, nicotin, and other substances are the same as those of human arteriosclerosis. The points of similarity are, however, too striking to be denied, and are, to all intents and purposes, the same, outside of the mode of causation.

The Presenile Type of Arteriosclerosis.—In addition to the senile type of arteriosclerosis previously referred to, which leads to the dry gangrene of the extremities, there is still another, a *presenile* type of acute arteriosclerosis, so-called "obliterative endarteritis" of Friedländer (1876), which causes gangrene of the extremities in otherwise apparently healthy men in the prime of life—between the twentieth and fortieth years. The disease usually attacks the lower extremities, beginning, preferably, in the left foot. It is essentially a disease of males (120 men to 7 women). It is a curious fact that the majority of these cases have been observed in Russian or Polish Jews. The combined statistics of Higier, Goldflam, Idelsohn, etc., show that in 58 cases there were 55 Hebrews. However, I have observed the disease in Anglo-Saxons and native Americans of non-Semitic origin, and do not believe it to be a racial disease. Syphilis, alcohol, diabetes, and premature senility can all be positively excluded in many cases. Hereditary influences may act as a predisposing cause, brothers and sisters often being attacked. Intermittent claudication, muscular cramps, and erythromelalgia in the lower limbs from ischemia usually precede the appearance of the gangrene, which, beginning in the toes, spreads gradually upward as a dry gangrene of the leg, often requiring amputation at the thigh. The pathology of this disease is explained in two ways: First, those who agree with Friedländer (1872) and von Winiwarter (1879), who attributed the closure of the vessel

to proliferation of the intima; and, second, those who interpret the process as a type of arteriosclerosis in which desquamation of the endothelium in the popliteal artery leads to a thrombotic (white) clot and occlusion of the arteries which progresses by peripheral extension. Quite recently, Leo Buerger has thrown the weight of histologic evidence in favor of the second view. He has demonstrated that the *veins* as well as the arteries participate in the process, hence the term "*thrombo-angiitis obliterans*" which he proposes. Thus far the essential cause of this remarkable lesion is unknown. Buerger's researches suggest a toxic origin.

FIG. 31.—ARTERY AND VEINS, SHOWING DIFFERENT STAGES OF THE OBLITERATIVE THROMBOTIC PROCESS. (Buerger.)
Above there are two recently thrombosed veins; in the center and below, an artery and vein are filled with sclerotic canalised tissue (× 18).

Polyarteritis nodosa (periarteritis nodosa) is a very rare and fatal form of acute arteritis, of which probably not more than 28 cases have been recorded in the literature since it was first accurately described by Kussmaul and Maier in 1866. It occurs in two forms: (1) as a multiple formation of small, nodular, spindle-shaped thickenings about the size of a shot, resembling a miliary tubercle, and (2) in another form they appear as small aneurismal dilatations which scarcely ever attain a larger size than a pea or acorn. Their common character is their great number on the same vessels or series of vessels, where they develop like beads strung on a thread. The disease almost invariably

attacks the visceral arteries of medium size, the mesenteric, hepatic, and other branches of the celiac axis, renal, coronary arteries of the heart, and the cerebral arteries. The age of the patients varies from childhood to adult life, and four-fifths of the reported cases have occurred in men. The clinical history is that of a general hemic infection with marked neuropathic manifestations. The diagnosis of typhoid, dysentery, peritonitis, intestinal obstruction, endocarditis, etc., is usually made until an autopsy occasionally reveals the true nature of the case. Only 2 reported cases have recovered. Nothing certain is known of its etiology. Rosenblatter, Freund, Jancso, and others believe that the arterial changes are the result of a specific infection. The disease is of interest to the surgeon because of the tendency to the formation of aneurisms (in 1 case over 63 were counted) and arteriothrombosis, especially in the mesenteric and other splanchnic vessels, where the disease is likely to cause surgical complications.

Syphilitic and tuberculous arteritis are specific types of arterial disease which only concern the surgeon indirectly. (See Vol. I., Chapters XVIII. to XXI.).

Observations of Interest in the Surgical Treatment of the Thrombo-arterial Obstructions of the Extremities.—In the observation of arteriosclerotic subjects in the advanced stages, it is important that the clinician should not overlook the preliminary signs which warn him of the dangers of progressive occlusion of the vessels of the extremities. As Zoege v. Manteuffel, Borchardt, and others have pointed out, long before the appearance of the gangrene the patient complains of disturbances referable to the diminished circulation in the arteries. In these cases a number of symptoms referred to the legs and feet, erroneously interpreted as rheumatism, articular disease, hysteria, flat-foot, broken arch, etc., fall under this category, even though gangrene fails to occur. These symptoms are pain, muscular spasms, transitory swelling of the legs, formication, psycho-paresthesia, sudden cyanosis or anemia, alternating sensations of heat and cold, pain and difficulty in locomotion, staggering gait, which may last a few hours or days and then disappear. These are the cases that Charcot sagaciously recognized as far back as 1856, and accurately described under the title of "intermittent claudication." In these conditions, as in the typical senile types of a teriosclerosis, when the warning signs occur, extra caution should be advised in preserving the limb from injury or infection, no matter how trivial, in order to prevent fatal inflammatory stasis and necrosis.

When gangrene actually begins, as it does gradually in the terminal stages of arteriosclerosis, in the farthest peripheral areas (toes), the question of amputation presents itself. *When* and *where* to amputate then becomes a serious question. The general rule of practice has been to wait until a line of demarcation has formed, unless a simultaneous ascending thrombosis of the arteries occurs, leading to a rapidly progressive gangrene, when immediate amputation is advised, high up, usually

above the knee. Other operators advise amputation at the *upper third of the leg*, others prefer the Gritti operation for anatomic reasons, others report cases in which amputation of the foot, even as low as Chopart's, Pirogoff's, and Lisfranc's lines, have been performed without sloughing of the flaps. Wide differences of opinion evidently prevail among operators of the present day. Low amputations are successful when the arteries are obstructed at a still lower point; they are followed by gangrene when the artery is blocked higher up. It is purely accidental when one operator happens to have cases with low arterial occlusion, so that his low amputations are successful, whereas others, with the same procedure, are obliged to resort to secondary and repeated amputations. What is needed in practice is some means of recognizing the viable parts which are still within the zone of active circulation. Hemorrhage from the stump at the point of section is usually regarded as a guide to the proper level of amputation, but this is fallacious, because many stumps in which the main artery does not bleed, nevertheless heal perfectly (Dollinger). It is in these cases that the "*hyperemia* test," recently suggested by Mozkowicz, will prove particularly valuable. Mozkowicz's test is applied as follows: The affected limb is elevated long enough to obtain a marked pallor of the skin, then a circular broad elastic bandage is applied around the thigh as high up as possible, and the constrictor is allowed to remain in place for five minutes. When the constrictor is removed, the usual hyperemic blush spreads over the limb, even though marked sclerosis be present. The hyperemic blush, however, is much less active as the ischemic areas of the foot or leg are approached. The red color spreads downward hesitatingly, almost imperceptibly, especially at the toes. Individual anemic patches persist for a long time, and the contrast between the red and the pale areas becomes marked in proportion with the extent of the arterial obstruction. It is evident that any operation within the pale zone will end in sloughing of the flaps. Mozkowicz, who has made numerous experimental and clinical tests with this method, shows very satisfactorily that the viability of the deep parts corresponds very closely with the living red skin areas, and that the surgeon may amputate with safety anywhere within the line of the pink or hyperemic skin. In this way conservative operations are favored, and there is less guesswork or accident in determining the proper level of amputation.

Catheterization of the Arteries.—When amputations are performed for senile or arteriosclerotic gangrene in which thrombosis has occurred in the vessels up to the level of the section, instead of reamputating higher up, it will often be possible to make the main artery bleed in the stump by clearing it of clot by gently introducing a soft catheter or bulbous tipped probe (dipped in sterile vaselin) into the vessel lumen; by following this with gentle massage or stroking of the limb toward the periphery, the artery is often completely cleared of clot, the blood flowing immediately from the cleared vessel. This procedure, known as the "catheterization of the arteries," was originally suggested and practised by Sevêreanu, of Bucharest (1895), and subse-

quently by Martin, of Angers, and Manquzat, of Mexico. I have adopted this procedure in all amputations in which the main vessels were blocked by thrombi, and always with gratifying results.

Thrombectomy.—In cases of embolic gangrene or when this is threatened, it would seem rational to open the artery at the point where it is plugged, remove the clot which is obstructing the blood-stream, suture the wound in the vessel, and restore the lumen. Simple as this may seem theoretically, there are many obstacles in the way of its satisfactory performance and in the accomplishment of its purpose.

Seven operations of this kind have already been reported: Sabanajew (1896), F. Lejars (1902), F. T. Stewart, Philadelphia, 2 cases (1907), Witzel (1907), Liene (1908), and, lastly, the case reported by Doberauer (Budapest) on July 3, 1907. In all instances but the last three the embolism occurred in the vessels of the lower extremities. In all, a thrombus re-formed promptly after its removal, and in all, except Witzel's and Doberauer's cases, the progress of the gangrene was not affected or arrested by the operation. Amputation had to be performed in all the cases. In Doberauer's patient (an axillary embolus) the clot was removed fifty-two hours after the signs of obstruction became manifest. Gangrene of the fingers with ischemic contracture of the forearm had already developed. In a few hours the artery, which had been cleared, again became blocked with a recurrent thrombus. The wound was reopened and the clot removed for the second time, the wound in the artery being closed again by suture. Thrombosis now followed for the third time in three hours after the second operation, and, as the gangrene advanced, Doberauer decided to create an arteriovenous anastomosis between the axillary artery and vein *above* the obstruction. Immediately after the establishment of the anastomosis the veins of the arm down to the wrist filled up, and the blood could be seen and felt circulating in the superficial veins. The successful reversal of the circulation in this case was demonstrated by the pulsation and other signs of arterialization of the veins. This case was reported twelve days after the operation, and the ultimate effect of this procedure on the progress of the gangrene is not stated. It is the first case in which arteriovenous anastomosis has been successfully established for the relief of recurrent embolic obstruction in an artery.

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OPEN WOUNDS OF ARTERIES.

These may be *penetrating* or *non-penetrating* and *perforating*. A *penetrating* wound divides all the coats of an artery and opens the lumen; *non-penetrating* wounds may cut through the adventitia or media, but do not involve the intima; they do not open the lumen of the artery. *Perforating* wounds (chiefly bullet wounds) penetrate the walls of an artery at two points. Wounds of arteries are also classified according to the degree of circumferential involvement into *complete* and *incomplete* sections; a *complete* wound interrupts the continuity of the artery; an *incomplete* or partial wound only involves a part of its circumference. An artery may also be injured with or without loss of substance, when a *partial* section of its wall is removed, or when a whole segment of the artery is cut off or otherwise detached.

According to the *mode* of *causation*, arterial wounds are classified into—(1) *punctured;* (2) *incised;* (3) *contused* and *lacerated;* (4) *gunshot wounds*. Besides projectiles, foreign bodies of various kinds may lodge in the vessel-wall.

Punctured Wounds.—These may be *penetrating* or *non-penetrating*. Puncture of an artery with a hypodermic needle is a typical illustration of this mode of injury in its most innocent form, as it leaves apparently no appreciable or permanent lesion behind it; the tissues seem to close about the tiny perforation without bleeding, provided it is removed forthwith. If a needle, no matter how fine, is allowed to remain in the lumen of the vessel, it will promptly lead to the formation of a coagulum made up of a mass of blood-plates and white corpuscles which become agglutinated to it. If the point of the needle is rubbed against the intima on the opposite side, so as to scratch the endothelium, it will soon lead to the formation of a white thrombus, consequent upon the irritation and damage done to the endothelium.

In accordance with the laws of vascular repair, the blood-plates and leukocytes will at once adhere to the injured surface and lay the foundation for the formation of a *white* parietal thrombus, which will continue to form and gain by accretion until the lumen of the vessel is totally obliterated unless the needle is removed shortly after its introduction. This white thrombus formation is always provided in the vascular system, for reparative and protective purposes, and is sometimes utilized in practice, as in the method suggested by Macewen, for obliterating certain inoperable aneurisms. If the penetrating instrument or weapon causing a punctured wound is infected, it will lead to the formation of a septic embolus or thrombus, to be followed, at the

point of occlusion, by a purulent thrombo-arteritis. Punctured wounds may be caused by scissor points, pins, needles, sharp-pointed fragments of bones in fractures, etc. Fatal hemorrhage may follow even apparently trivial punctured wounds when these involve the great arterial trunks

Not long since in my own practice a girl of fifteen years was killed by her younger brother who, in a fit of anger, threw a pair of scissors at her; the sharp point of one of the blades entered the right subclavian artery above the clavicle, and death followed in a few minutes, before help could reach the victim. Scarcely a drop of blood escaped externally, but an enormous hemorrhage had filled the pleura. A number of fatal hemorrhages from the penetration of the aorta by fish-bones and sharp-pointed fragments of bone and foreign bodies lodged in the esophagus are reported by Paulet and others. At one time punctured wounds of the brachial, at the bend of the elbow, were not rare, when the practice of venesection was universal, and was practised by the barbers as well as regular physicians. No immediate effects were noticed at the time, but arteriovenous aneurisms often developed (see Arteriovenous Aneurisms). Punctured wounds in which foreign bodies lodge, as in the neck, when the carotids are injured, may lead to serious secondary consequences (hemiplegia from embolism of the brain, etc.).

Incised Wounds.—Incised, *non-penetrating* wounds which do not involve the intima are apparently of little consequence. Bouglé, who had experimented with the view of creating aneurisms by parietal incisions and excisions of the adventitia and lumen, and by denuding the artery of its sheath, has always found that the wounds heal without evil effect of any kind in healthy animals. The *incomplete incised wounds* of arteries are classically divided into the *longitudinal, oblique,* and *transverse.* A longitudinal wound, which runs parallel with the long axis of the vessel, tends to retain its linear appearance; a *transverse wound,* on the contrary, will gape wide open; the original cut is linear, but is immediately transformed into a circular or oval outline. The opening by a transverse wound will be three or four times larger than that from a longitudinal incision. The hemorrhage from such a wound will, therefore, be three or four times greater, and spontaneous hemostasis will be proportionally difficult to obtain. These differences between the longitudinal and transverse wounds are important from the operative point of view, because the transverse cuts, which involve three-fourths of the circumference of the vessel, cannot be sutured by lateral arteriorrhaphy on account of their great retraction; whereas, the longitudinal, even of considerable length, can be so treated. Therefore, also, longitudinal incisions (arteriotomy) should be preferred for the removal of thrombi or even bullets which may have migrated from other parts, and the vessel closed by suture after clearing its lumen, with the expectation that the circulation in the vessel will be restored if the intima is not badly injured (Schlosser).

A *complete transverse section of an artery is less dangerous than an incomplete* wound which does not sever the continuity of the artery at the injured point. Complete wounds bleed less because the cut end immediately retracts and contracts within the sheath, so that the

lumen of the vessel is very much narrowed. In a large dog the femoral artery will retract to the extent of 2 or 3 cm. or even more, between the divided ends, especially if the thigh is extended. By the narrowing of the divided ends the lumen of the vessel is very much reduced, friction is increased at the outlet, and spontaneous hemostasis is favored. When the artery is only partially divided, retraction is interfered with, the wound remains gaping wide without retraction, and spontaneous hemostasis is interfered with.

Gunshot Wounds.—*Symptomatology.*—This is all summed up in the word hemorrhage. When a large artery is opened, hemorrhage will occur and blood will flow until the organism, as a whole, succumbs, unless the group of phenomena, which are summed up in the phrase "spontaneous or natural hemostasis," take place. The first step in this process is the formation of a clot or thrombus at the constricted mouths of the divided vessel, where it acts as a plug or stopper; this is known as "provisional hemostasis." If this provisional thrombus is not detached by external accidental conditions or the excessive pressure of the blood current, it will become organized—*i. e.*, it will be transformed gradually into a cicatricial plug made up of connective tissue—thus constituting the *final* or *permanent hemostasis.*

Temporary Spontaneous or Natural Hemostasis.—The cessation of hemorrhage, without outside intervention or surgical help, depends largely upon the caliber of the vessel injured, the structure of the vessel-wall, the degree of intravascular pressure, the region involved, and the size and nature of the wound in the vessel. The contraction of the lumen of a divided vessel results from the direct irritation of the muscular fibers of the artery and is a biologic reaction. Its influence is greatest in those arteries in which the muscular coat is best developed. It is the organism's first effort at self-protection. At the same time the elasticity of the artery causes a longitudinal as well as circular retraction of the vessel within its sheath. This narrowing of the caliber of the artery extends for a considerable distance beyond the point of section. The longitudinal elastic retraction withdraws the artery for a considerable distance from the surface of the wound within its cellular sheath. This is a purely physical phenomenon and can be demonstrated upon the dead body. These changes, which narrow the caliber of the vessel sometimes from one-half to one-quarter of its original diameter, are immediate and they are quickly followed by the formation of the obliterating thrombus or clot. *This thrombus, as it is formed in the living blood-vessels, is very different from the simple clots that* are formed outside of the body. The blood in escaping from the mouth of the injured vessel comes in contact with a cut edge of injured tissue, often of irregular contour, and flows into the sheath and the surrounding tissues before it reaches the surface. The mere contact with the injured cellular elements of the intima and of the damaged cells of the perivascular tissues at once favors coagulation by the action of the *plasmase* of the tissue-juices which contains the fibrin ferment and precipitates the fibrin of the blood.

Red or Passive Clot and its Functions.—As a result of this precipitation of fibrin, a red clot now forms, of the kind first described by Broca as *passive* clot. It is a soft, non-resistent material, made up of a mesh of fibrin which has entangled the red and white cells, but particularly the erythrocytes. By the force of the blood-current it breaks up almost as fast as it is formed. This red clot, formed by chemical action solely, would never effectively arrest the bleeding; but, by filling up the perivascular tissues and the space between the sheath and the retracted blood-vessel, it retards the violence of the blood-stream, which is already reduced in volume by the contraction of the wound orifice and by the lowered tension of the blood resulting from the primary extravasation. By this combination of conditions the clot not only forms externally, but extends into the lumen of the vessel, where it continues to increase in density until it reaches the nearest collateral, where the current sweeps by

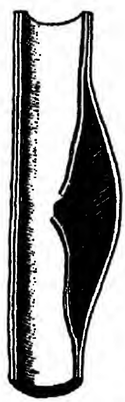

FIG. 32.—SPONTANEOUS HEMOSTASIS IN A LATERAL WOUND. (Diagrammatic.) (Bouglé.)

FIG. 33.—PROVISIONAL HEMOSTASIS IN TRANSVERSE WOUNDS. Plug and cap clot. (After Follin and Duplay.)

with too much velocity to allow of the further extension of the thrombus.

The White Thrombus and its Functions.—As a result of this temporary plugging or obstruction, the velocity of the current is very much reduced at the outlet, and an opportunity is then given to the blood-plates, which always travel with the leukocytes in the periaxial stream, to linger and adhere to the cut surface, and, in this way, a much stronger and more efficient plug is formed, known as the *white thrombus*. This is entirely different in its structure from the red or passive thrombus. We have already stated that the formation of a white thrombus is invariably associated with injuries or lesions of the endothelial lining of the blood-vessels. It always appears wherever there is injury that requires protection and repair. This white clot (the "inflammatory lymph" of the old observers) is made up entirely in its first layers by blood-plates which become adherent to the injured surface, where they become agglutinated in

enormous numbers and blend ultimately to form a plastic homogeneous deposit upon which leukocytes and fibrin filaments become attached, and in this way form a cement. This sticky, white mass, extending from the edges of the wound, gradually occludes it, forming a firm and resisting wall of far greater efficiency than that of the provisional inert non-glutinous red clot, which acts chiefly as a temporary *obturator* and *buffer* against the blood-current, while the active cellular clot is being formed.

The formation of this white thrombus and its intimate structure has been especially studied by Zahn, Pitres, Eberth, and Schimmelbush, who describe it not as a process of coagulation, but as a *conglutination*. This corpuscular conglutination upon the endothelial surfaces, which have lost their power of self-protection, is observed as the first defensive phenomenon whenever and wherever blood-vessels are injured, not only in man, but throughout the animal kingdom. It has been observed in arthropods, birds, and the higher vertebrates (Loeb), and in fact is, in the majority of the lower forms of animal life, the essential and all-important mode of thrombus formation. It is only in man and the higher vertebrates that we find the precipitation of fibrin as a secondary phenomenon added to the conglutination of the cellular elements of the blood.

We thus find that, in natural or spontaneous hemostasis, there are two kinds of thrombus formation, as previously stated: (1) a red clot, which only serves to retard the blood flow mechanically, and is made up of red and white cells plus fibrin, and (2) a white or corpuscular clot, which is made up of blood-plates plus leukocytes plus fibrin. The white thrombus thus formed rapidly narrows and obliterates the bleeding orifice, leaving the red thrombus undisturbed outside of the vessel, where it forms a cap or mantle, and the internal clot or stopper ("*bouchon*" of the French) which extends up to the first collateral branch. When this provisional thrombus is completed, it appears on section very much like a nail or long tack with a broad mushroom head, the peg, represented by the internal clot, being driven into the lumen of the vessel from the outside.

In *partial, parietal,* or *incomplete wounds* the white thrombus forms a plaque resembling an exudate, which may or may not extend circumferentially into the vessel, remaining, as a rule, as a mural thrombus, where it officiates as a protective layer until definitive or final organization and repair of the damaged elements have taken place.

The spontaneous process of hemostasis, above described, is aided in particular cases by certain other conditions:

(1) *Contusion of the Artery.*—If in place of a clean cut with a knife the artery is bruised or lacerated, the brittle middle and inner coats give way first and curl up inside of the artery. On the curled ends coagulation quickly takes place, and hemostasis is almost instantly secured. This is the basis of the surgical principles involved in the use of the écraseur, the cold or hot snare, the angiotribe or crushing forceps, etc.

(2) *Laceration of the artery,* by traction or twisting, acts much in the same way. Contusions and lacerations are potent auxiliary factors in obtaining mechanical hemostasis, because—(*a*) they occlude the vessel provisionally, by the curled-up inner and middle coats; (*b*) by increasing the area of endothelial degeneration, which favors the formation of white clots; (*c*) by increasing the perivascular trauma and again favoring the greater liberation of the tissue juices which furnish the coagulating agents ("plasmase," Duclaux).

(3) *Long, tortuous, narrow tracts,* forming valvular wounds; dense, aponeurotic spaces which confine the blood in small spaces.

(4) *Diminished arterial tension,* brought about by *sudden arterial* depletion and shock. The degree of intravascular pressure has a most important bearing on the spontaneous arrest of hemorrhage. The greater the intravascular pressure, the greater are the difficulties to be overcome in the arrest of bleeding by thrombus formation. Cohnheim says: "When a gap or defect is produced at any point in the vascular system, all resistance ceases there and the blood will in consequence flow toward it and escape through the aperture with an energy which is naturally greater the higher the pressure in the part of the vascular system involved." *A thrombus once established obstructs the lumen of a blood-vessel injured just so long as its adhesion to the orifice of the wound is sufficient to resist the intravascular pressure* (Senn).

(5) Shock produces an immediate fall of the blood-pressure; and this alone in injuries of the large vessels will suffice to bring about a syncopal state, which may be salutary if it occurs before a great mass of blood is lost.

(6) *Increased Coagulability of the Blood.*—This tendency is increased in normal individuals by repeated or progressive hemorrhage.

Provisional hemostasis is retarded by—(1) Partial division of the artery, which is thereby kept open and unretracted. (2) Adhesion of the sheath to the blood-vessel, as occurs in inflamed tissues, thus preventing the retraction of the artery. (3) Unrest, disturbance of the injured region by movements or manipulations which displace the clot. (4) Stimulation of the heart and circulation artificially by drugs which increase the force of the systolic contraction (digitalin, strychnin, ammonia, alcohol, etc. (5) Hemophilia, scurvy, and purpuric states. (6) Bleeding into large serous cavities, where no mechanical resistance is offered to the escaping blood.

Permanent Spontaneous Hemostasis (Organization of the Thrombus).—*Cicatrization and Final Healing of the Arterial Wound.*—After the provisional hemostasis is obtained and the arterial thrombus is fully formed, the organization of the clot begins. The provisional thrombus is entirely passive in the course of cicatrization. Once obturation and hemostasis is obtained, the function of the thrombus is: (1) To act as a cushion or buffer against which the impulse of the blood is received, and in this manner to prevent any disturbance of the plastic processes which are in progress at the seat of the injury; (2) to form a framework or scaffold to support cell invasion, as the embryonal endothelial cells and angeioblasts proceeding from the walls of the vessel

invade the thrombus on all sides; (3) to serve as nutriment for these cells, which are all endowed with phagocytic properties.

Though the clot is a dead and inert mass and takes no part in the living processes, by which the final closure of the vessel is secured, a deficiency of clot, when an artery is damaged, may be a predisposing factor toward persistent, recurrent, or secondary hemorrhage, by the displacement of a thrombus when a large collateral opens close to the seat of injury. At one time it was taught that the leukocytes participated in the building of the new tissue or scar; but it is now universally recognized that the cicatrization of the artery takes place here, as in wounds of other tissues, by the multiplication or karyokinetic subdivision of the fixed tissue-cells of the intima and of the media. This great mass of embryonal cells group themselves into typical granulation tissue, such as is found in wounds elsewhere. This granulation tissue takes the place of the clot, and is itself subsequently transformed from the embryonal type to the mature type of connective tissue.

Permanent obliteration of the artery at the injured point is the final consequence of wounds of all arteries (veins and lymphatics also) in which hemostasis is obtained by the organization of an obturating thrombus. Sometimes the cicatrized thrombus is canalized or perforated, allowing a modified lesser circulation to continue in the wounded vessels; but complete occlusion is the rule. It is only when the closure and repair of an arterial wound is obtained by suture applied according to the rules of modern technic (see Arteriorrhaphy) that healing is obtained without an obturating thrombus formation.

Influence of Infection on the Organization of the Clot.—When the wound becomes infected with pyogenic microörganisms and these gain access to the provisional thrombus, a septic thromboarteritis is established and the reparative process is interrupted. The clot is at once invaded by a host of leukocytes, which, engaging in a struggle with the invading bacteria, soon convert the clot into a soft, puriform mass which undergoes disintegration. By thorough drainage and other antiseptic measures the wound may be purified and the germs eliminated, giving a chance to the embryonal cells to multiply and form the necessary granulation tissue. Not until this is accomplished can definite healing of the artery be expected.

SUBCUTANEOUS INJURIES.

Contusions or Bruises; Ruptures; Lacerations; Tears by Grinding or Attrition; Stretching or Twisting.—When a blow is struck over the skin and soft parts covering the path of a large artery, the vessel, in virtue of its mobility and elasticity, may be merely displaced or turned aside and thus escape violence altogether. More often the coats of the vessel will be injured to a greater or less extent, and yet the continuity of the artery will be preserved. Again, the vessel may be crushed through, so that its continuity is completely interrupted; or it may be torn across by stretching, or, again, severed by spiral twists, as when a limb is

caught in a machine accident and made to turn upon its axis. All of these injuries may be *direct*, as when the wheel of a heavy cart or a railroad car crushes through the thigh or leg; or *indirect*, when an artery, for example, the axillary, is torn through by the head of the humerus which is suddenly displaced forward in the axilla; or, what is more frequently the case, when the vessel is ruptured by violent efforts to reduce an old dislocation. Likewise the popliteal and femoral are sometimes ruptured in attempts to break up old adhesions in the knee and hip. It is easily understood that the extent of the injury will vary with the intensity of the traumatism, and that in this way all degrees of injury may be exhibited by the affected artery.

Contusion.—With Delbet, Bouglé, and the French authors we may also recognize different degrees of contusion. In the *first degree*, the intima or internal tunic alone is involved, and a small local defect or alteration in the intima will follow, which may be covered over by a protecting layer of blood-plates, fibrin, and leukocytes, constituting a white thrombus. This will adhere and protect the injured surface as a flat parietal plaster until the damage is repaired. In these trivial injuries the defect will be healed without interrupting the circulation in the artery, as the lumen is not completely occluded. As long as this

FIG. 34.—INCOMPLETE RUPTURE OF AN ARTERY FOLLOWING A CONTUSION. (Bouglé.)

is the case the outward or clinical manifestation of the accident will be insignificant.

In the *second degree* of contusion the media and intima are both torn and become detached from the adventitia. The two coats then curl up like a scroll and retract within the lumen of the vessel, thereby forming valve-like projections which vary considerably in length, according to the violence inflicted. The vessel is then simply held together by the thin but tough adventitia, which bridges over the gap and preserves the continuity of the vessel. The immediate effect of this injury is to produce a thrombus which will at once block up the artery. The vessel-wall will also be so much weakened that it may tear at the injured point after feebly resisting the pressure of the blood that slowly filters through the curled-up inner and middle coats which block up the lumen of the vessel. When extravasation occurs, it is not until several days have elapsed; then an appreciable hematoma forms, which usually does not increase rapidly; but this, together with the ischemia of the distal parts, will disclose the true nature of the case.

In the *third degree* all the three coats are torn across and the continuity of the vessel is interrupted. The torn ends of the vessel will now retract, and its lumen, thus narrowed, with the aid of the hemostatic thrombus, will suffice to close up the artery and thus pre-

vent any extensive hemorrhage into the surrounding tissue; or, what happens more often, the hemostasis thus obtained is soon followed by the displacement of the clot and a large subcutaneous hemorrhage occurs. The effects of these various injuries may be summed up into—(1) hemorrhage, (2) gangrene, (3) traumatic hematoma, and (4) false traumatic aneurisms, which may be circumscribed or diffused.

Causes of Mortification after Arterial Contusion.—Mortification or gangrene of the distal parts, as it usually presents itself in the lower limbs, owes its frequent occurrence to at least two conditions: (1) An arterial subcutaneous rupture, usually followed by a large extravasation of blood which is pent up tightly under the aponeurosis, muscles, and unyielding peri-arterial tissues as in the popliteal space. The concealed bleeding here continues until the extravascular pressure outside of the artery is equal to the intra-arterial tension. The great tension under which the blood is kept on account of the unyielding nature of the surrounding tissues causes a displacement of the soft parts and an obstructive compression of all the tissues in the vicinity of the injured artery. As a result, the important collateral branches which should convey the blood to the distal parts are also blocked up to a large extent in the neighborhood of the injury to the parent trunk. (2) The provisional hemostatic clot which plugs up the mouth of the torn artery is liable to break up on the distal side and to be displaced and thrown into the peripheral circulation as multiple emboli which block the peripheral vessels. (3) In crushing injuries of sufficient severity to cut through the vessels of the limbs, especially the popliteal and femoral, *all the soft parts*, including the secondary arterial branches which cross the line of contusion, participate in the injury and are, in turn, "blocked up." In this way all accessory or secondary sources of collateral supply to the distal parts are cut off coincidentally with the "blockade" of the main trunk.

Pulsating Hematoma and Traumatic Aneurism.—When a complete subcutaneous rupture of a large artery takes place, two events may follow in addition to, or apart from, gangrene: (1) a circumscribed pulsating hematoma, also described as a false consecutive or circumscribed traumatic aneurism, or (2) a non-pulsatile diffuse hematoma. The second form of hematoma usually occurs in regions in which the blood can extravasate and diffuse itself without much resistance, as in the axilla, the groin, the thigh, and wherever the intra-arterial pressure is sufficient to overcome the resistance of the superficial musculo-aponeurotic planes and fascia. The blood then escapes progressively into the tissues, diffusing itself widely and in every direction, so as to cause often enormous swelling of the limbs. The swelling does not pulsate. The appearance of the limb is characteristic. It becomes cold, pulseless, livid, and anesthetic; the skin is tense, discolored by ecchymoses, hemorrhagic blisters, and in places looks as if it would burst. The entire limb from the groin to the ankle may soon swell to giant proportions; not only in consequence of the enormous extravasation but also as the result of the secondary edema which follows the

obstruction or compression of the veins and lymphatics. The general effect of hemorrhage will be felt and be manifested by the signs of anemia, shock, and general exhaustion. These will be aggravated by the gangrene of the limb, which will promptly supervene if the fatal tension is not quickly relieved by surgical interference.

Complications.—The danger of peripheral gangrene is always made doubly worse by the simultaneous injury of the accompanying or satellite vein, which, occupying as it does an adjoining compartment of the same sheath with the artery, usually suffers the same lesions as the artery. When the artery alone is injured and gangrene follows, this is usually of a dry type. If the vein is involved also, moist gangrene will result.

Infection and Suppuration.—Sometimes these extravasations are followed by infection and suppuration causing grave pulsating hemorrhagic abscesses, which bring with them all the dangers and perils of infected aneurisms.

Symptomatology and Diagnosis.—Injury of a large vessel may be suspected when very extensive extravasations or hematomas develop in regions which have been subjected to much strain, stretching, or other forms of direct or indirect trauma, as in the axilla after forcible attempts have been made to reduce an old dislocation of the shoulder. If a systolic friction murmur is heard above the seat of the injury and a thrill is felt by the hand on pressure over the injured artery, a large arterial wound is probable. This bruit, which was first described by v. Wahl in 1880 (the sign of von Wahl), is intermittent, isochronous with the pulse; of a blowing, scraping character. It is distinguished from the murmurs obtained in arteriovenous injuries by the fact that it is heard with greatest intensity at the seat of injury, and is transmitted along the lumen of the artery in a peripheral direction for a short distance only. This sign, which is heard in punctured, incised, or gunshot wounds of the arteries, is most evident when the injury of the artery involves only a part of its walls and when the circulation in the vessel has not been wholly interrupted. The sound is caused by the contraction of the vessel at the injured part, either by a thrombus or by the retraction or curling in of the intima and media. It is sometimes present when the arteries are completely divided and the blood enters the distal end, after diffusing itself through a circumscribed hematoma. The von Wahl bruit is not heard in the smaller arteries, or whenever the arteries are obstructed by a thrombus.

The appearance of the limb; the absence of peripheral pulse, the pale, cold, shrivelled skin, at once tell of arterio-thrombotic occlusion. When the limb is choked up, swollen, cyanotic, and, later on, there is no dehydration of the fingers, there is evidently likewise a venous obstruction.

The **prognosis** of these injuries is intimately related to—(1) the extent and severity of the trauma; (2) the presence or absence of the thrombus; (3) the presence or absence of the collateral circulation; (4) associate injuries of bones, joints, nerves, and organs; (5) the region

involved. The influence of the region involved in the injury in deciding as to the probability of gangrene is five times as great in injuries of the lower as in those of the upper extremities.

Cases of this type, in which the artery has been lacerated subcutaneously by direct violence, have been especially studied by Lejars (1898), Picquet (1906), A. Schorong (1905). Schorong reported 45 cases (in which Lejars' statistics are included) and classified them as follows: Popliteal, 20 cases, all terminating in gangrene of the limb; femoral, 11, followed by gangrene in 7; brachial, 7, with gangrene in 1; iliac, 2, with gangrene in 2; axillary, 1, with no gangrene; ulnar, 1, with gangrene 1; radial and ulnar, 1, with 1 gangrene; carotid, 1. Total, 32 cases with 75 per cent. gangrene.

Treatment.—When a subcutaneous injury occurs in the track of a large artery and a rapidly increasing hematoma develops, immediate effort should be made to control the bleeding by circular compression with the Esmarch elastic constrictor at the root of the limb on the proximal or cardiac side of the swelling. When the axillary, carotid, or femoral regions are involved and circular constriction at the root of the limb is impossible, the main artery must be controlled by direct digital pressure or by exposing the artery at a distance from the seat of injury and securing it with a provisional traction loop by which the circulation of the artery may be controlled by an assistant. Instead of the loop of thread, a soft padded clamp, on the Crile or Hoepffner pattern, may be adjusted to the artery as a means of provisional control of the circulation. After it is evident that the circulation in the main trunk supplying the injured region is well under control, a free incision should be made in the long axis of the swelling, in order to evacuate the clotted mass and allow of free access to the injured artery. Here the judgment of the operator will be taxed at times in deciding upon the operative procedure—whether to ligate and obliterate the vessel according to classic rules or to attempt the preservation of its lumen by lateral or circular suture. In the upper extremity, below the origin of the profunda, the risk of gangrene after ligation is so slight that the ligature can be applied to the brachial with safety. This should be done by ligating the artery above and below the tear or wound and dividing or excising the injured part between the ligatures. If the circulation is well controlled on the proximal side above the wound, it may be well, before tying the ligatures, to explore the vessel for thrombi, which may extend for a considerable distance above and below the seat of injury, and in this way contribute largely to the danger of peripheral gangrene by obstructing the origin of important collaterals. This can be done by the use of a spiral-tipped whalebone guide, such as is used for the exploration of urethral structures, or a soft-rubber catheter, well lubricated with sterile vaseline.

In the lower extremities, more especially in the popliteal region, when the vein is coincidentally injured in crush-wounds, gangrene is so certain to follow in the peripheral parts that, up to very recent times, the rule was invariable to amputate above the knee at once

without waiting for gangrene to develop for fear that septic infection would follow, as the gangrene under these circumstances is of the moist and septic variety. At present the rule is to cut down upon the injured vessels the moment it is evident that they have been injured. A free incision is made to the seat of injury, and the operator must decide between several courses—(1) If either vessel is in fair condition and there is only a lateral tear, after clearing out the clot in the lumen, gentle saline irrigation and sponging, perform a lateral arteriorrhaphy and apply the same method to the vein (lateral phleborrhaphy). (2) If either the artery or vein is lacerated so as to involve three-fourths of its circumference, divide the vessel, clear out the thrombus, and suture it by direct end-to-end anastomosis by the technic to be described subsequently. (3) If the vessel is so extensively damaged that a resection (arteriectomy) is required exceeding three-fourths of an inch of the vessel, and it is evident that the divided ends cannot be approximated by any of the methods of circular suture, then a biterminal arteriovenous anastomosis may be established by the transplantation of a satellite vein or a section, *e. g.*, of the opposite saphenous, according to Carrel. In view of the certainty of mortification of the leg and foot in these double injuries, this method, in spite of its uncertainty, may be given a trial by an operator who has confidence in his technic. Otherwise, the old plan of ligating each end of the divided vessel after clearing out the thrombus in both the artery and the vein, will undoubtedly be the safest and best practice. It is barely possible, in young subjects especially, that by relieving the perivascular tension of the popliteal space, clearing out the thrombus, and limiting the obliteration of the vessel strictly to the injured area, an opportunity will be given to the collaterals, if any remain uninjured, to carry blood to the distal parts and save the limb, with a minimum of peripheral necrosis.

When arterial obstruction has occurred, without gangrene following it, the limb should be carefully wrapped up and kept warm by artificial means, and immobilized in a well-padded splint until the collateral circulation has had time to develop. If gangrene has already occurred, amputation should follow after the line of demarcation has formed. When moist gangrene is threatened, every precaution must be taken to prevent septic infection and putrid decomposition by a thorough application of occlusive antiseptic dressings. Should the patient develop an encysted or circumscribed pulsating hematoma, then the same rules apply as in the treatment of ordinary traumatic aneurisms.

Ligation of the main trunk at a distance, to control the bleeding in progressive extravasations and hematoma, should always be avoided, as it is liable to be followed by secondary hemorrhage, but this ligature may be applied provisionally, merely as a traction loop, while the arteries are exposed at the seat of injury and ligated, or otherwise secured by the methods previously referred to.

Ligations in continuity are justified in exceptional cases only, as in certain injuries of the neck and head, in which it is im-

possible to reach the bleeding branch without very serious injury to the surrounding or vital parts. Ligation of the main trunk instead of the bleeding branch is also permissible in certain gluteal injuries (often of difficult access to the direct method of ligation); possibly, also, in some visceral injuries involving the peripheral branches of contused and lacerated organs (kidneys, spleen, intestines), in which the ligature of the main trunk is permissible as a preliminary to the extirpation of the damaged organ. But even in these exceptional cases every effort should be made to control the bleeding artery in accordance with the golden rule, "ligate at the bleeding point."

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Treatment of Arterial Wounds.—This may be subdivided into constitutional and local, in accordance with the general indications presented by the hemorrhage, which is the fundamental fact to consider in the treatment of wounded arteries.

The constitutional treatment of hemorrhage and other not strictly operative or *direct* methods of dealing with the wound in the artery, in order to arrest the hemorrhage, will be considered under the section on Hemorrhage. We shall, therefore, confine ourselves in this section to the consideration of—(1) Compression; (2) forcipressure; (3) torsion; (4) acupressure; (5) ligation; (6) suture; (7) plastering (Brewer) and patching of arteries (Carrel, etc.); (8) transplantation of vessels.

The surgeon's real weapons against hemorrhage are forcipressure with the hemostatic clamps, which are used not only as a direct means of arresting bleeding, but also as a prophylactic hemostatic in the daily routine of surgical operations; torsion; the ligature and the suture. In the treatment of arterial wounds "the method of election is the ligature: forcipressure is a method of necessity; and the suture is the ideal method," the last method, at present, undergoing a rapid evolution and destined to become very soon the method of election in dealing with the clean wounds of the larger arterial trunks. Grafting and plastering the arteries, by patching with transplanted grafts or with adhesive and other extraneous mechanical devices, as well as transplantation of vascular segments, are still in an experimental stage.

Compression is the readiest, the most effective, and logical of the provisional or temporary hemostatics. It may be *immediate* and *direct* when pressure is made at the bleeding point, *e. g.*, by pressing

with the finger over the bleeding spot or by pinching the lips of a bleeding vessel between the fingers; also, when an aseptic tampon or gauze pack is applied to a bleeding surface and held firmly in position until the ligature or suture can be applied to secure a permanent hemostasis. *Mediate, indirect* pressure is applied when digital or instrumental compression is made over the main trunk of an artery which gives origin to the bleeding vessel. It is applied at the most accessible point on the cardiac side of the wound. It is often done when the injured and bleeding vessel is too near the trunk to permit the application of the elastic circular constrictor (Esmarch) or when other constrictors and tourniquets are inapplicable. Usually, immediate direct compression is resorted to solely as a provisional hemostatic measure; but sometimes, when there is extensive oozing, it is allowed to remain in the form of a plain sterile tampon, sachet, or pack impregnated with antiseptic and styptic remedies (compound alum powder; ferripyrin; adrenalin solution; gelatin solution, etc.) and packed firmly in a deep open wound when the bleeding is, as previously stated, more capillary or venous than arterial. In hemorrhagic subjects (hemophilic, icteric, purpuric), whose wounds bleed and ooze obstinately from constitutional rather than local causes, this method of compression with stypic packs is also most valuable.

Forcipressure.—To the use of the improved hemostatic forceps is largely due the enormous advance accomplished in recent years in the technic of surgical operations. The hemostatic forceps, when applied to an artery, crushes the internal and middle coats of the vessel; the external tunic resists and holds the edges of the internal and middle coats which have been crushed by the instrument, and in this way preserves to some extent the continuity of the vessel. If the forceps is allowed to remain *in situ* for a minimum period of sixteen hours, an artery of the caliber of the radial will be permanently obliterated without requiring other means of hemostatic control; if it is allowed to remain forty-eight hours, an artery of the caliber of the femoral will be completely obliterated. Aseptic forcipressure (provided no infection occurs) obliterates the artery permanently by adhesive or plastic endarteritis, the vessel becoming subsequently transformed into a fibrous cord at the point where it has been crushed by the forceps. If the pressure is not continued longer than an hour, a partial thrombus may form at the crushed point—provided the vessel is of large caliber—the thrombus organizing ultimately, leaving the lumen pervious. While forcipressure remains one of the most efficient, ready, and satisfactory means of obtaining prophylactic and actual hemostasis in the field of the operation, the tendency is not to utilize these as permanent hemostatic agents as freely and systematically as when Koeberle, Péan, Richelot, Segond, and their pupils first popularized them in pelvic and vaginal surgery. The compression of the tissues en masse—*i. e.*, including a large amount of perivascular tissue with the blood-vessel—causes a necessary necrosis and pain, and a ligature which is strictly limited to the vessels is preferable. Nevertheless, the hemostatic clamps

render inestimable service whenever the ligature of an almost inaccessible artery or vein is difficult or impracticable.

Historical.—Forcipressure, as at present understood and practised, owes its origin to the advocacy and example of Koeberle, of Strassburg (1865), and to Péan (1867), who was chiefly instrumental, by his persistent and powerful advocacy, in popularizing this method of hemostasis throughout the surgical world. In English-speaking countries the influence of Sir Spencer Wells was particularly felt in advancing the propaganda in behalf of this method.

Torsion and **angiotripsy** are derivatives of forcipressure. Torsion, or the twisting of arteries, at one time so popular, has given way largely to the aseptic absorbable animal ligature, which accomplishes the same result with greater certainty and without irritation. It is still in constant use in dealing with the smaller vessels, but it is no longer practised on the large arteries. In performing torsion of a large vessel, the end should be isolated for half an inch at least, the isolated portion grasped transversely with a pair of hemostatic forceps, and the projecting end grasped in its long axis with another forceps, which is then twisted around its axis until the tunics are torn sufficiently to form a mass of shreds, strong and intricate enough to completely block up the artery for half an inch above its terminus. On the other hand, if a vessel can be treated by torsion, it is sufficiently accessible to apply ligature, which is just as quickly done and is more reliable. Torsion should never be attempted on friable arteries, arteriosclerotic vessels, or on the visceral arteries. Its field of usefulness is now restricted almost entirely to the small arteries and bleeding points encountered in the field of the operation.

Angiotripsy or **vasotripsy,** meaning the crushing of the blood-vessels by a mechanical device, is a hemostatic method which originated with Maunoir, in 1820, who was followed by Amussat and Spier. These older inventions, however, have little in common with the present powerful crushers introduced by Doyen in 1897, and since modified by a great many imitators. Doyen's instruments (there are models of different sizes) can apply, progressively, a pressure of 800–1200 kilos to the surface of the vessel held in the bite of the instrument. This powerful vasotribe crushes not only the blood-vessels, but all the tissues that it holds in its bite, completely transforming the histologic structure of the part crushed into a thin, unrecognizable, ribbon-like tissue, and, in this way, with a comparatively little delay, large pedicles, such as are found attached to ovarian tumors and the broad ligaments, are reduced to the thinness of a semitranslucent, fine tissue-paper. Doyen, however, does not recommend that his vasotribe should be used exclusively as a hemostatic agent. He simply advocates this method as a means of reducing the thickness of heavy vascular pedicles, broad ligaments, omentum, the mesentery, and even to crush the intestines as a preliminary to the performance of enterectomy; the advantage of this reduction is that instead of the large cumbersome and heavy

ligatures that would be otherwise required to control the bleeding, a small ligature is sufficient.

Holländer has recently invented a small hand forceps which, by special leverage, greatly multiplies the crushing power of the ordinary hemostat without materially increasing its size. It is intended as a substitute for the torsion or ligature of the smaller bleeding points.

FIG. 35.—DOWNES' ANGIOTRIBE IN OPERATION. (Kelly-Hurdon.)

The base of the appendix is converted into a flat, translucent cord by Downes' electrothermic angiotribe. The right-hand figure shows the appearance of the tissues, the meso-appendix divided and the appendix about to be amputated in the direction of the arrow, as shown by the left-hand lower figure.

Electrothermic Angiotripsy.—The principle of combining galvano-cauterization with a crushing of the blood-vessels with forceps was first successfully applied by Skene, of Brooklyn, N. Y. He was inspired by the results obtained by the elder Keith, of Edinburgh, who systematically applied cauterization with the actual cautery or hot iron to the pedicle of ovarian tumors, after crushing and ligating them. Skene contended, with very convincing statistics, that the combination of

cauterization with pressure was not only a very effective substitute for the ligature as a hemostatic agent, but that it was far more efficient than any other method in preventing local recurrence after hysterectomy for cancer of the uterus.

This method, however, has been brought to the greatest degree of efficiency by Downes, of Philadelphia. His method has found many strong advocates, among them C. P. Noble, Howard Kelly, and J. W. Bovée, the latter having reported in 1905 203 abdominal and 27 vaginal operations, in which Downes' apparatus had been applied as a preventive hemostatic. The essential elements of the electrothermic method of Downes are: first, and of the greatest importance, pressure and heat. The angiotribe is applied to the tissues, to be "hemostased," and the compressed ribbon thus formed is rapidly submitted to a temperature of not under 212° F., thus coagulating and agglutinating, under pressure, its albuminous constituents. In addition, the heat travels a short distance beyond the area compressed into the adjacent tissue, and causes a shriveling of the intima of the blood-vessel, leading beyond the ribbon. Clotting, therefore, occurs a considerable distance beyond the ribbon. In this instrument, the heating medium is an insulating ribbon of iridoplatinum, which becomes red hot or even white hot by the resistance it offers to the passage of a suitable electric current. Bovée, after a most extensive trial, gives it his unqualified indorsement in vaginal and suprapubic hysterectomy, appendectomy, ovariotomy, intestinal resection, nephrectomy, splenectomy, etc. The disadvantages of the method are the degree of accidental injury of adjacent organs in the pelvis by excessive heat, the necessity of great precision in its employment to avoid this excess of burning, and also the care constantly required to keep the apparatus in good working order. In the 230 cases reported by Bovée he had two hemorrhages, not imputable, however, to the method. The instrument is now used in many of the clinics of this country to meet special indications.

The Ligature.—The ligature is mentioned by Celsus and Antyllus, by Paulus Aeginetus, by the Arabian, Avicenna, in 908, and by others. After this early period nothing more is heard of the ligature until it was brought to light by Paré's practical genius (1507–90). It was only through his dominant personality and untiring zeal that the ligature gradually found its way into professional favor and displaced the barbarous treatment of hemorrhage by pouring boiling oil and cauterizing the blood-vessels with a hot iron, which was in vogue up to that time. The application of the ligature became more intelligible, and its applications were expanded by the momentous demonstration of the circulation of the blood by Harvey (1616). It was launched with still greater impetus by the genius of Hunter and the brilliant galaxy of men—Jones, Travers, Abernethy, Sir Astley Cooper, Béclard, Scarpa, Porter, Desault, Dupuytren, Anel, and so many others whose names still remain as monuments to the ceaseless surgical activity of the latter part of the eighteenth and earlier part of the nineteenth centuries. Finally came the Listerian discovery, which thirty-five years ago gave us the aseptic absorbable ligature. This has been progressively improved into its present practically finished form, and has made possible not only the advances of surgery in all its new and vast possessions but also the

finer technic of the aseptic suture of the blood-vessels as the latest expression of its highest evolution.

Action of the Ligature; Healing of Arteries after Ligation; Fate of the Ligature.—The main facts involved in the application of the ligature, including the process of cicatrization in an artery after aseptic ligation, may be summarized in the following propositions: (1) The essential factor in the obliteration of a ligated artery is the proliferation of the endothelium of the intima; the embryonal cells resulting from the multiplication of the connective-tissue cells of the two outer tunics and those of the endothelium (fibroblasts) and plasma cells, uniting to form a typical granulation tissue which is vascularized by the angioblasts from the vasa vasorum, as well as from the endothelium. When this granulation tissue matures, a permanent cicatrix is formed which obliterates the artery. (2) The clot or thrombus formed at the seat of ligature may appear one hour after the ligation and is not likely to be delayed beyond six hours. The more aseptic the ligation and the less the traumatism to the coats of the vessels, the smaller the clot and the longer will it take to form. In the small vessels, the coagulation takes place up to the nearest collateral branch. In the larger vessels this

FIG. 36.—THE INNOMINATE ARTERY TIED WITH STAY KNOTS. (Ballance and Edmunds.)

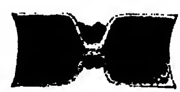

FIG. 37.—THE COMMON FEMORAL ARTERY TIED WITH A STAY KNOT. (Ballance and Edmunds.)

varies. The proximal clot is generally the larger. Immediately above the ligature an apparent dilatation is observed (the ampulla of Bryant) due to the presence of the clot and the constriction of the vessel above it (J. Collins Warren). The clot does not distend the vessel; it fits the tube loosely, and a space frequently exists between the clot and the vessel-wall (Fowler). (3) The organization of the clot by the embryonal cells of the endothelium after ligation is but another illustration of the general law which underlies all vascular repair. Thrombi, wherever formed, whether in the blood-vessels, in the heart chambers, in the loose connective-tissue spaces (hematomata), or in the adventitial sacs of traumatic aneurisms, are all organized—*i. e.*, are transformed into fibrous masses by the substitution of a living embryonal connective tissue—in place of the passive coagulum, after this has subserved its protective function. (4) In normal arteries and in aseptic conditions complete obliteration may take place without the appreciable formation of clot if care is taken not to injure the intima or media. Practically, however, even in conditions of absolute asepsis, the formation of a thrombus at the seat of ligature is unavoidable, but it will become an insignificant element in the process if the vessel coats are not injured and pyogenic microörganisms are avoided. (5) The leukocytes and other formed elements of the blood play no part in the organization of a clot, as was formerly taught by Virchow and others,

but become very active factors in its disintegration, whenever an infected ligature is used and the thrombus is invaded by bacteria. (6) When infected ligatures are used, a septic pan-arteritis is developed which is quickly propagated to the endothelium. The presence of bacterial toxins is immediately followed by an enormous invasion of polynuclear leukocytes; a thrombo-arteritis is established, which leads, first, to an extension of thrombus in the vessel and then to its rapid disintegration and purulent liquefaction. The ligature, then, acts not only as a foreign body, but as an irritant; all the reparative processes in the vessel-wall are arrested; the ligature ulcerates its way through and is cast off with the pus. Finally, the soft puruloid thrombus, unable to resist the pressure of the blood-column, is forced out and secondary hemorrhage occurs. (7) In applying a ligature in continuity, sufficient force should be used to obliterate the lumen with a minimum of injury to the vessel-wall. Obliteration of the great arteries of the first magnitude may be obtained without rupturing the middle and inner coats of the vessel by occluding the artery with as broad an approximation of the endothelial surfaces as possible. This is obtained by adopting the double or treble stay knots recommended by Ballance and Edmunds (see chapter on Ligation of Arteries). In the aseptic ligation of the smaller arteries the laceration of their coats is not only an unavoidable, but a safe practice. (8) While in the aseptic ligation of arteries the detachment of the vessels from their sheath is not necessarily attended by serious nutritive disturbances in consequence of injury to the vasa vasorum, it is always preferable to detach the sheath no more than is necessary for the proper application of the ligature. (9) The fate of the ligature depends largely upon the material used and the conditions in which it is applied. The fate of an aseptic ligature made of an organic material (catgut, tendon, silk, etc.) is to become encysted and then absorbed; even silver, lead, iron, and other metallic sutures become ultimately absorbed; only gold or platinum appear to be the exceptions. All ligature materials of animal origin at present in use are ultimately disintegrated by phagocytic cells.

(10) The preferred material for the ligation of arteries is catgut or silk. Silk remains encysted in the tissues for a practically indefinite length of time, and catgut is absorbed in a variable time, according to its size and mode of preparation. For the various methods of its preparation, see p. 598.

In the suture of arteries, as we shall see later, silk or linen is necessary, because the very fine needles used for this delicate work cannot be threaded with any form of catgut.

(11) If the ligature has not been tied with sufficient firmness, or if the knot has slipped, or there is too rapid softening of the ligature, the circulation through the vessel may become reëstablished. Again, it may happen that a diaphragm is formed at the seat of constriction with a perforation in its center, which will allow the reëstablishment of the circulation through the strictured vessel (Ballance and Edmunds).

(12) The *collateral circulation* by which the peripheral parts are nourished after the occlusion of a large regional artery by a ligature or a thrombus, is dependent for its development upon several factors, some of which have not been fully accepted by all pathologists: (1) Reactionary afflux of blood in the ischemic or vascular territories and organs resulting from a stimulation of the blood sense (blood hunger) of the tissues deprived of blood. The cry for pabulum on the part of the fasting tissues is responded to by the nervous system in the form of a vascular reaction (vasodilator) which leads to an immediate dilatation in the unobstructed arterioles adjacent to the blocked vessel. The hyperemia immediately following the removal of an Esmarch bandage applied to a limb illustrates this theory or principle (A. Bier's theory).

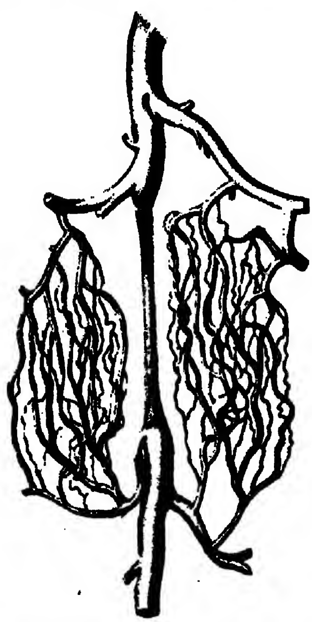

FIG. 38.—COLLATERAL CIRCULATION AFTER LIGATION. (Marwedel.)

(2) The unobstructed arteries in the vicinity of the ischemic territory not only dilate actively (vasomotor dilatation), but force the blood toward the distal parts by automatic rhythmic contraction of the muscularis of the media which acts independently of the heart. (3) The obstruction of the main artery of a region by ligation or otherwise will increase the general arterial pressure above the obstruction proportionally to the cross-section of the area cut off from the general circulation. Thus the general blood-pressure will increase in an ascending ratio as the caliber of the ligated arteries increases, reaching its maximum when the abdominal or thoracic aorta is ligated or suddenly obliterated; the systolic work of the heart increasing proportionally with compensatory hypertrophy or ending in fatal progressive dilatation from overstrain (Katzenstein's theory). (4) By these combined factors the collateral vessels adjacent to the obstructed artery are rapidly dilated and thickened (hypertrophied). With the gradual dilatation and increased pressure brought to bear upon the vessels on the proximal side of the obstruction, the peripheral resistance also diminishes. This continues until the sum of the cross-section of the collaterals equals that of the suppressed artery, the peripheral parts again receiving as much arterial blood as before the obstruction occurred. (5) The circulation may also be reëstablished in the ligated trunk below the ligature by (*a*) direct continuation of the blood-stream in the proximal and distal branches, (*b*) by the reopening of the lumen of the vessel at the point of constriction, owing to the yielding of a thin

cicatrix; (c) in cases of thrombotic occlusion, by the canalization of the clot.

Causes which Interfere with the Establishment of the Collateral Circulation.—(1) Traumatic or mechanical damage to the tissues of the region involved as a whole, including the branches of the obstructed artery, as in railroad and other injuries which crush limbs transversely to their long axis. (2) Interstitial compression and occlusion of the collateral branches of the main trunk by extensive diffuse extravasations or hematomas. (3) Diseases of the arteries—arteriosclerosis and arteritis—which prevent their dilatation and adaptation to the demands of the altered circulation; (4) coincident obstruction of the satellite veins and lymphatics, thus favoring stasis in the peripheral circulation.

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Rules for the Ligation of Wounded Arteries.—A series of rules or guiding principles known as the "golden rules" for the ligation of bleeding arteries have been formulated and are classical in English surgical text-book literature since the days of Guthrie, when the emergencies of military surgery, as they arose in the great Napoleonic campaigns, made their value as practical guides to the operating surgeon most apparent. These rules have been more or less modified by the gradual development of surgical technic, but, in spite of their antiquity, still remain unaffected in their essential value, except in a few notable instances which we shall indicate in our commentaries. These rules were admirably summarized by Dr. John B. Roberts in his Text-book of Surgery, published in 1890, and I shall quote them in full with the additions and commentaries that have suggested themselves to me as necessary in order to adapt them to the progress of contemporary surgery.

I. "*In cases of primary hemorrhage do not ligate arteries which are not actually bleeding at the time, but have the patient carefully watched.*"

"*Reasons for this Rule.*—(1) It is very possible that bleeding has ceased permanently. (2) It is difficult to be sure of the artery from

which the bleeding came. (3) All manipulations in wounds are to be avoided, unless demanded by special conditions."

"*Exceptions to this Rule.*—(1) When the injured vessel is plainly seen pulsating in the wound. (2) When the occurrence of very slight recurrent or secondary hemorrhage would be disastrous—as in a very anemic patient. (3) When, as in transportation, the patient will necessarily be removed from surgical scrutiny."

[*Commentaries.*—(*a*) In military practice the rule of non-interference is observed even when a large hematoma or diffuse extravasation follows a gunshot or other deep injury, and is associated with characteristic bruit (von Wahl) and other evidences of wound of an important artery. These hemorrhagic accumulations should not be opened and the artery ligated unless the hematoma is distinctly progressive and diffused. If the hematoma remains well defined, it is the better practice, after applying a supporting, occlusive and immobilizing dressing, to send such patients to the reserve hospitals, where they can be treated as traumatic aneurisms with far less risk of infection and gangrene than in the field hospitals.

(*b*) In civil practice, when all the conditions for a good aseptic technic are available, all such arterial or pulsating hematomas, even though stationary and well defined, should be opened, the clot removed, and the artery secured by ligature or suture at the wounded point. When there is evidence that a profuse arterial hemorrhage has taken place, the bleeding artery should be exposed, ligated, or otherwise secured (sutured, if possible) after the patient has rallied. In the pre-antiseptic period this practice would not have been justified.—R. M.]

II. "*In cases of primary and secondary hemorrhage, the ligature should be applied when practicable in the wound, at the point where the artery bleeds and not in the continuity of the vessel.*"

"*Reasons for this Rule.*—(1) It is frequently impossible to know which artery is injured until the wound is opened. (2) Secondary hemorrhage may occur after ligation in continuity from the establishment of the collateral circulation. This secondary bleeding may come even from the proximal end of the cut vessel, if a branch of considerable size is given off between the wound and the point of ligation. (3) Ligation in continuity makes a second wound, and adds the possible complication of this wound to the patient's original danger and increases the chances of gangrene in the periphery.—[R. M.] (4) Ligation in continuity remains, as a reserve step, still possible, if ligation in the wound fails."

"*Exception to this Rule.*—None."

[*Commentary.*—Since this rule was first established by the military observations of Guthrie and Larrey, the experience of over a century has only served to emphasize the soundness of this Golden Rule.—R. M.]

III. "*If the artery is completely severed, both ends should be tied; if it is partly divided or punctured, a ligature should be applied to the vessel on each side of such a wound, and the artery divided between them.*"

"*Reasons for this Rule.*—The collateral circulation will probably cause secondary hemorrhage from the distal portion of the vessel, unless double ligature be adopted."

"*Exception to this Rule.*—When the distal end cannot be found, pressure should be made in its vicinity."

[*Commentary.*—When the cut edges are sound (as in incised wounds) and the wound is longitudinal or oblique, and does not involve more than two-thirds of the circumference of the vessel, and there is no infection, the attempt should be made to close the wound in the vessel by lateral suture without obliterating its lumen. When the artery is of the first magnitude and when its obliteration may lead to gangrene, as in the femoral or the popliteal, even when the vessel is completely divided, an attempt should be made to restore its continuity by *end-to-end* anastomosis and thus restore the circulation in the main trunk. The importance of this recommendation in cases of the joint injury of both artery and vein is still more evident. Extensively crushed, contused, and lacerated vessels are not fit for suture, but may be resected and made amenable to other methods of restoring their continuity. Venous grafting or arteriovenous anastomoses are methods which are too experimental at the present time to justify their recommendation as *rules* of practice.—R. M.]

IV. "*If a large artery is wounded near its origin, tie it below the wound and tie the trunk from which it arises, both above and below the point of origin of the branch. If a trunk is wounded near the origin of a large branch, tie the parent trunk with two ligatures in the ordinary manner and apply a third ligature to the branch.*"

"*Reasons for this Rule.*—The force of a large current of blood, near the internal coagulum, may lead to its displacement and cause secondary hemorrhage when a silk ligature causes ulceration of the external coat or a catgut or flat ligature is absorbed."

[*Commentary.*—In all cases in which the obliteration of the main trunk or branch may lead to serious circulatory disturbances in the distal parts (carotid, iliac, femoral, popliteal) the wound should *be sutured*, if it be on the trunk, and the adjoining collateral, next to the wound, ligated. If the injury involves the collateral close to the main trunk, the collateral should be tied on each side of the wound and divided between ligatures, *without ligating the main trunk*. If the wound involves the branch too near the trunk to permit of ligature, instead of ligating it and the main trunk (as the rule commands), the collateral should be completely detached and the wound of the main trunk sutured, while a ligature on the branch will prevent collateral hemorrhage on the peripheral side. This old rule should still apply only in those violent traumatisms in which it is impossible to restore the continuity of the main trunk by any mode of suture. The rule was established as a result of the old experience with the septic ligature, when the thread was expected to be eliminated by ulceration; it was also very proper in the days when the obliteration of the ligated artery was wholly dependent upon the organization of the thrombus; and when suppuration and secondary hemorrhage were the rule and not the exception. At present, when the ligature does not ulcerate through the artery and obliteration is obtained by adhesive or plastic proliferation of the intima, and when primary union is the rule and not the exception, it is no longer mandatory. It still holds good, however, in all septic and suppurative wounds in which infection of the lateral ligature or suture is unavoidable.—R. M.]

V. "*Only when it is impossible or impracticable to tie the vessel in the wound, as in deep injuries of the neck, head, and pelvic vessels (gluteal and*

sciatic), is ligature in continuity permissible"—*e. g.*, ligature of internal iliac for gluteal injuries; of external carotid for tonsillar hemorrhage.

[*Commentary.—Never ligate the main trunk of an artery for the control of hemorrhage at a distance, when the branch that directly supplies the bleeding region can be secured.* This applies to all the large arteries, but particularly to the common carotid, which is often ligated for tonsillar, maxillary, lingual, and other hemorrhages which could be controlled by the ligation of the *external* carotid, thereby avoiding the dangers of secondary cerebral degenerative disturbances, especially in arteriosclerotic and aged subjects.—R. M.]

VI. "*Always ligate the main trunk of an artery at a distance from the nearest collateral when given off at a bifurcation.*"

Example.—External carotid.

[*Commentary.*—For reasons given in Rule IV. this old precept does not hold at present when the ligature is applied to a main trunk in aseptic operations, as the presence of a collateral branch in the neighborhood of an aseptic ligature does not increase the risk of secondary hemorrhage if primary union takes place. On the other hand, while it is true that an aseptic ligature can be applied on a collateral branch close to the main trunk without incurring any risk of secondary hemorrhage, it is, nevertheless, quite possible (when the ligature is applied close to the bifurcation of a large artery) for the thrombus to be detached from the ligated artery and be swept into the adjoining artery with disastrous consequences to the distal parts. This is particularly true of ligatures placed on the external carotid, close to the bifurcation. Here a clot will form sometimes immediately after the ligation, and, in spite of the most perfect asepsis, be swept to the circle of Willis, with the immediate development of hemiplegia, aphasia, or other cerebral disturbances. It is also possible that in applying a ligature to the profunda, close to its origin, the superficial femoral may be blocked by an embolus.—R. M.]

Provisional ligatures for temporary hemostasis have been tried experimentally and clinically with various materials (silk, catgut, elastic bands), with the object of controlling the peripheral circulation and securing a bloodless field, as well as of minimizing the loss of blood; also with the view of preventing the entrance of blood into the air-passages, which is a frequent cause of post-operative pneumonia. The carotids, iliacs, femorals, the aorta, and subclavians have been the vessels especially thought of for this purpose, as circular constriction with a tourniquet is impracticable for prophylactic hemostasis in these regions.

Technic for Provisional Ligature.—After exposing the artery by a typical incision the ligature is passed and the vessel tied with just sufficient firmness to insure the occlusion of the lumen without injuring the intima. Bothezat, Bouglé, and Faure (who applied a provisional elastic ligature to the aorta to control peripheral circulation while performing an inter-ilio-abdominal amputation) have especially studied this question in France; Schoenborn, Senger, Riese, in Germany; and the conclusions arrived at are that the temporary ligation

of the vessels is permissible on condition that the ligature be tied with just enough force to secure the obliteration of the lumen without injury to the tunics of the vessel. Even under these conditions the constriction is not to be prolonged more than one hour and preferably less (Bouglé). The pressure obtained by the elastic ligature is cumulative and liable, therefore, to do more harm than the silk or catgut ligature. *Mediate*, provisional ligature, as originally practised by Coselli and others, consists in tying a ligature over a gauze pad which protects the artery partially from the direct action of the ligature.

Temporary obliteration of the lumen of a vessel by angular traction with a silk or catgut loop passed under the vessel and held in the bite of a forceps or by the hand of an assistant is a far safer procedure and has been used more often, probably, than any other method of direct provisional hemostasis. This method and all the others mentioned are uncertain in their effects upon the coats of the vessel. The exact degree of constriction depends largely upon the judgment of the individual operator, and if a traction loop is used the pressure is likely to be variable. In moments of alarm the assistant may pull up the vessel with a degree of tension that will be permanently resented by the tissues, and, as is known to me personally, predispose to the development of aneurism in favorable subjects at the seat of the traction.

The method of direct instrumental compression with finely adjustable clamps is a safer procedure, as it is less dependent upon the variable personal equation of the operator or of his assistants.

Temporary Instrumental Compression for Prophylactic Hemostasis.—For this purpose a number of adjustable clamps have been devised, of which, perhaps, the best models are Crile's, Aleggiani's, Hoepfner's, Pozzili's, and the serreplats of Langenbeck, which have served such good purpose in the hand of Murphy and Carrel. I also have devised a clamp for temporary compression of the main trunk above and below an aneurism, with a view of controlling not only the main trunk, but the more important collaterals that are given in the vicinity of the pole of the sac. This special clamp, somewhat like a forceps described by Glück thirty-five years ago, will be referred to again in connection with the treatment of aneurism.

A number of arterial compressors have been devised for the mediate compression of some of the larger arteries, more especially the aorta (Erichsen's, Skey's, Signoroni's, etc.), and also for direct (intraperitoneal) compression of the aorta in controlling the circulation of the vessel for the cure of aneurism—*e.g.*, Keen's aortic compressor. But the object that we have in view at present is the direct compression of an artery exposed and isolated by dissection with a suitable mechanical device, which will temporarily interrupt its peripheral circulation. The effect of occlusion of the vessels has been recently studied by Crile. In his experiments he used the clamp (Fig. 39), which he devised for the purpose and which he applied especially to the control of the carotid areas. The immediate effect on the circulation of temporarily closing one carotid artery was to increase the general blood-

pressure, but compensation soon followed. There was no effect on respiration. Simultaneous closure of both common carotids causes greater rise in the blood-pressure, which gradually returns to normal. In some experiments the clamps were allowed to remain on the carotids until the wounds healed, the wounds healing aseptically as in normal conditions. Even after twenty-four hours of complete closure no *apparent* damage was done to the vessel-wall. If the carotid wound became infected, then serious damage to the vessel resulted. In no case was there clotting, emboli, or thrombi.

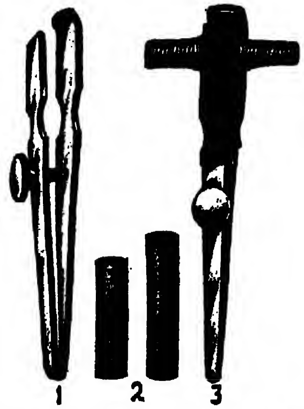


FIG. 39.—1, CRILE'S CLAMP; 2, RUBBER TUBING FOR SLIPPING OVER THE ENDS OF THE CLAMPS; 3, CLAMPS APPLIED TO ARTERY. (Fowler.)

Intermediate Ligation or Suture (*Ligature or Suture en masse*).—This designation was originally applied to the ligation of a large arterial trunk with all the surrounding parts, when it was not easy to isolate the vessel. It was simply a relic of the crude technic of the days of Ambroise Paré, who, even in amputation stumps, would include nerves as well as other structures in his large coarse ligatures. At the present time the ligature of the tissues *en masse* is always avoided, but in its place the *aseptic absorbable catgut suture* is used to control parenchymatous oozing in large wounds, as in amputations through muscular regions, where it acts as a hemostatic, obliterates dead spaces, and brings into apposition large raw surfaces. A large curved needle threaded with catgut is whipped over the oozing area as a continued whip-stitch; or is used sometimes as a purse-string suture which encircles the raw area and compresses it, bringing it together (as in the end of a stump). The use of this buried absorbable suture for approximating deep muscular planes and aponeuroses, whether as a continued or interrupted stitch, is gaining in favor in surgical clinics whenever it is desirable to close a wound without drainage or to diminish the area of cicatrization to a minimum.

In addition to the ligature of large pedicles *en masse* and of other tissues in which, for any other reason, the individual vessels cannot be separately ligated, the ligature may be used to strangulate a vascular growth not only in the external surfaces of the body but also in the viscera; as in the case of angeioma of the liver, reported by Keen, in which he applied an elastic ligature to the pedicle of the tumor and removed it after it had been completely extraperitonealized and strangulated.* The suture *en masse* is also of great value in the preventive as well as actual control of hemorrhage in the friable parenchymatous organs, like the liver and spleen, in which the ligation of the individual blood-vessels is usually very difficult or impracticable.

In this connection the ingenious suture methods devised by Koustnetzoff and Penski (1896), of Ceccherelli and Bianchi (1894), Auvray (1897), Carl Beck (1902), Cullen (1905), Payr and Martina (1905), J. Frank, Chicago (1905), are notable illustrations of the utility of the massive suture, with or without prothetic aids, in the control of visceral hemorrhage. For a critical review of these methods, see W. E. Schroeder, Chicago, "Surgery, Gynecology, and Obstetrics," Vol. II., January, 1906, and Garrè, Vol. V., September, 1907, of same publication.

THE SUTURE OF ARTERIES—ARTERIORRHAPHY.

The history of the suture of arteries begins with the notable suggestion of Lambert, a surgeon of Newcastle-on-Tyne, who, impressed with the dangers of the ligature as practised in his day, induced his colleague, Hallowell, to try to close a wound in the brachial artery which had been injured in a recent phlebotomy. The operation was performed on June 15, 1759, and though a crude method was adopted,—a harelip pin run through the edges of the arterial wound, held with the figure 8 over it,—it was a perfect success as far as the healing of the wound and the apparent restitution of the circulation. This fruitful and valuable idea was destined, however, to remain sterile, because Assman, in 1773, found that, while the suture was an effective hemostatic, it led to the obliteration of the artery by thrombosis. The dominant idea of the time, that thromboses immediately followed any irritation or injury of the blood-vessels and that repair could not take place in an artery without its obliteration by a clot, led to the universal acceptance of Assman's experiments as final, and no attempt was made to revive Lambert's suggestion for nearly one hundred years. It was not until the Listerian doctrine had given a new impetus to experimental research in surgery that the long silence was broken by Glück in 1882, who, in spite of the numerous and ingenious experiments he performed, met with scant success. Postempski, of Rome, in 1886, succeeded in closing a lateral wound of the femoral artery which he had caused accidentally while draining an iliac abscess, and thus inaugurated the modern method of suture with the first successful arteriorrhaphy in man after Lambert's case. Matas followed, in 1888, with the suture of the bleeding orifices in a traumatic aneurism of the brachial artery, which had resisted both proximal and distal ligations. Then an active experimental period followed with v. Horoch's (Vienna) experiments in 1888, and the great work of Jassinowski of Odessa in 1889. A large number of publications followed, in which the names of Burci, Ceccherelli, Lampiasi, Muscatello, Clementi, and Robert Abbe, of New York (1894), are conspicuous.

The active interest of modern practical surgeons in the suture was not aroused, however, until J. B. Murphy published his now classic paper of 1897, and demonstrated by his numerous and brilliantly successful clinical as well as experimental results with his method of invagination, that end-to-end anastomosis was possible without the obliteration of the artery. After Murphy's publication, the status of the suture as a practical surgical procedure became thoroughly established, and the reports of cases and of experiments multiplied in the literature so that at present it may be said that arteriorrhaphy has been practised in some form by almost every surgeon of large experience all over the world.

Thus far the application of the suture had been restricted largely to the closure of arterial wounds in continuity. The less frequent indications and more difficult technic of circular arteriorrhaphy have kept the number of reported cases of this procedure at a very low figure (24 cases to November, 1908; 120 cases of arterial suture up to October 1, 1906).

The results in the lateral arteriorrhaphies have been satisfactory with very few exceptions as regards hemostasis, and apparently, as far as could be determined,

good from the functional point of view. A doubt remains, however, as to the permanent patency of the lumen in a considerable number. There is one failure from tearing of the sutures due "to excessively high blood-pressure" (Brewer). One secondary hemorrhage in an axillary artery lacerated in reducing a dislocated shoulder; the hemorrhage coming on twenty-one days after suture, without assignable cause (Körte); in one case gangrene followed the suture of the popliteal, injured while resecting the upper tibia for sarcoma (Rotter's case). In all, 6.4 per cent. immediate failures.

It is very likely that a great many cases in which accidents have occurred have not been reported, but, taken as a whole, the results are very satisfactory.

Since October 1, 1906, when this compilation was completed, a great many valuable experimental and clinical contributions have appeared which attest to the growing interest of surgeons in the application of the suture in the various phases of vascular surgery. These additions to the statistics are too numerous to be even quoted in an article of this scope and purpose; furthermore, they are only confirmatory of the conclusions above stated. Apart from lateral arteriorrhaphy, the value of the suture, as a substitute for the circular ligature, has been most frequently and effectively demonstrated in the treatment of peripheral aneurisms by the intrasaccular suture of the arterial orifice, by the method suggested by myself. The reports in this respect show a steadily increasing number of contributions (106 cases up to February, 1909).

Classification.—Arteriorraphy may be *lateral* or *circular* (end to end). In either case, the suture may be "aided" by extra-vasal supporting appliances, which may be permanently imbedded in the tissues (ivory, decalcified bone, magnesium rings, glass tubes, rubber or horn plates, etc.), or by temporary supports, which remain in the lumen of the vessel only during the act of approximating the edges (see de Gaetano's method, Fig. 50, *A*). When the supports are used in the vessel lumen, they are "endo-vasal"; when outside, they are "extra-vasal." The endo-vasal prothetic aids are no longer used (see Abbe's method, Fig. 50, *B*). Of the numerous "aids" suggested and devised for this purpose, the magnesium rings of Payr (see Fig. 47) alone survive (see Crile's Technic for Blood Transfusion). Circular arteriorrhaphy may also be classified according to the procedure adopted, as will be seen under the heading "Circular Arteriorrhaphy."

The Technic of the Suture.—While no one questions now that the *lateral suture* of the large arteries is very nearly as practical, safe, and certain a procedure as the suture of the large veins has proved to be, after a much longer experience, there are still some few questions in the technic that have not been definitely settled until quite recently. In regard to the much-debated question, whether a suture should be interstitial or perforating, the accumulated evidence all shows that the through-and-through suture of the *edges* of an arterial wound (including the intima) is not only easier, more secure, but safer than the partial suture, which includes only the two outer coats. This was conclusively proved experimentally and clinically by Dörfler, Heidenhain, Silberberg, Israel, Lindner, and the majority of those who have followed them. This is particularly true if, in making the suture, accurate apposition of intima to intima is maintained.

Technic of lateral arteriorrhaphy, for longitudinal, oblique, or transverse wounds, not exceeding half a circumference of the artery.

With *aseptic* precautions, the sheath of the artery is exposed and opened with the least possible injury to the vessel and surroundings. If the circulation has not been controlled by a constrictor or some form of pressure on the central side, the main artery is compressed with the finger or gauze pack until the two ends are more permanently held with suitable padded clamps, which will be readily adjusted and which will obliterate the lumen of the vessel without constricting it. Carrel uses a pair of Langenbeck's clips, but Hoepfner's forceps or a pair of long-bladed, thin elastic spring forceps with a long ratchet, and padded with thin rubber, will do. These should be applied at a distance from the line of suture. In dealing with some of the arteries the Joani procedure (Figs. 40–42) may be adopted; this has the advantage of controlling the bleeding, while the artery is held straight and ready for suture. In other cases, especially longitudinal wounds, Joani's long angular forceps can be

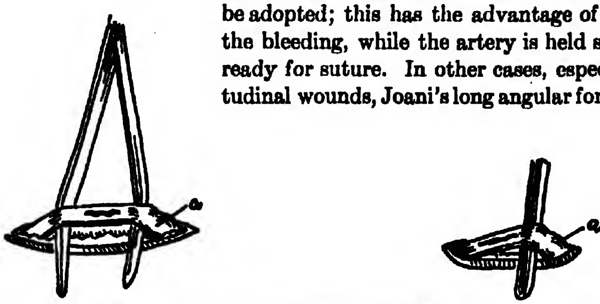


FIG. 40.—JOANI'S METHOD OF ISOLATING AND EXPOSING ARTERIES FOR LATERAL ARTERIORRHAPHY.

used with advantage to approximate the edges of the wound, and also bring the intima in apposition while the sutures are being introduced. After provisional hemostasis has been obtained, it is important that contusions, bruises, or other injuries of the endothelial edges of the wound be avoided and that no toothed forceps be used unless it be just within the margin. It is preferable when no special forceps are at hand to begin by applying a traction suture at each end of the cut, penetrating through the thickness of the coats close to the margin, just sufficiently to lift up the edges of the cut, and thus bring the endothelial surfaces in apposition. Thus a

FIG. 41.—JOANI'S METHOD OF ISOLATING AN ARTERY AND VEIN PREPARATORY TO LATERAL SUTURE: *a*, Artery; *b*, vein.

simple continued suture can be whipped over the wound with great rapidity and accuracy, or an interrupted mattress suture (Joani) or a continued mattress (Dorrance) may be used. The simple whip stitch with the traction threads at each angle accomplishes all that is required in the simplest and most expeditious manner. In applying the stitch, no matter by what method, we must imitate Carrel by using the very finest silk or Alsace thread No. 500, unless the vessels are of large caliber, when milliner's or fine cambric needles with elongated eyes, or "floss" needles, sizes 6–10, threaded with a No. 0 or 1 oculists' silk may be used. Also following

Carrel's example, the thread should be soaked in sterile vaselin and the edges of the wound lubricated with the same substance, in order to prevent thrombus formation. See that the thread fits the eye of the needle to prevent oozing at the punctures if the needle is larger than the thread. For the smaller arteries, such as the femoral and popliteal, the best results will be obtained by using the finest needles made for lace manufacturers by English makers. The Kirby needles, Nos. 16, 17, and 18, recommended by Carrel, which will carry a No. 500 silk, will accomplish the best results. The lips of the wound are penetrated immediately opposite each other at intervals of about 1 to 2 mm. ($\frac{1}{25}$ to $\frac{1}{12}$ inch), so as to secure close coaptation. Gentle traction should be made on the thread, after the passage of each stitch, so as to approximate the edges as quickly as possible from the start, care being taken to avoid the inversion of the edges. The principle of *intima to intima* is to be always kept in mind, just as serosa to serosa is the guiding principle in intestinal

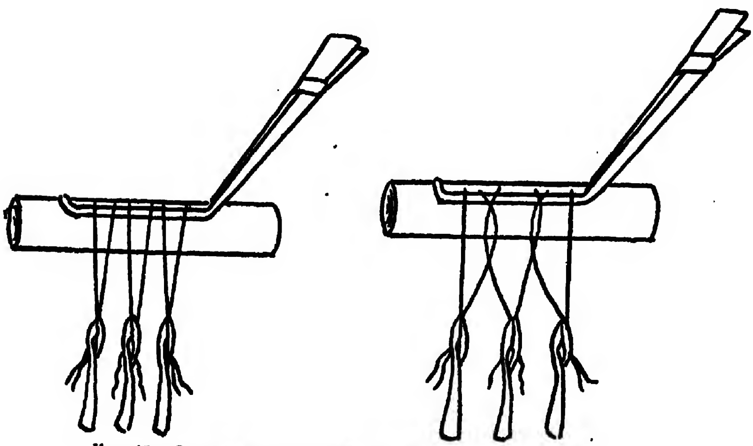


FIG. 42.—JOANI'S CLAMP APPLIED IN LATERAL ARTERIORRHAPHY.

suture. The sheath of the artery is separately sutured over the vessel and this should again be supported by bringing together with buried sutures the overlying soft parts, muscles, or aponeuroses, and the wound closed without drainage.

Circular Arteriorrhaphy.—While there is no longer any doubt as to the practical value and safety of the lateral suture, the judgment of experienced surgeons is still uncertain upon the choice of the simplest and safest method of performing a circular or end-to-end anastomosis. The choice of procedures now rests between (1) the invagination method of Murphy; (2) the aided invagination method of Payr, in which absorbable magnesium rings are used to support the invagination, or (3) the method of broad marginal confrontation of the intima (Salomoni-Jaboulay-Briau method), or (4) the direct marginal approximation of the divided vessels by the triangular or prismatic suture of Carrel.

The methods of invagination, bearing in mind Murphy's method as the fundamental procedure, are open to the objections (1) that they narrow the lumen of the intussuscepted vessel and (2) that they leave a raw, exposed line inside the lumen of the artery in contact with the blood, thus favoring thrombosis by the liberation of the plasma juices

in the vessel lumen; and (3) all the invagination methods compel more stretching and take up more material to obtain a secure apposition

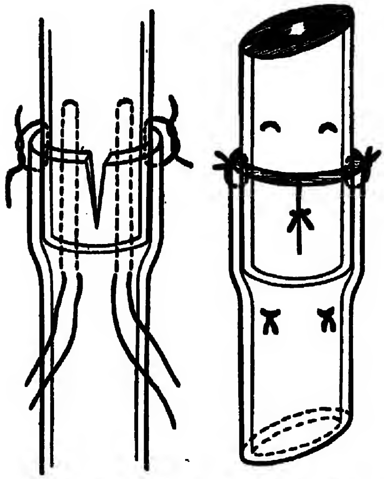


Fig. 43.—Murphy's Invagination Method of Arteriorrhaphy.

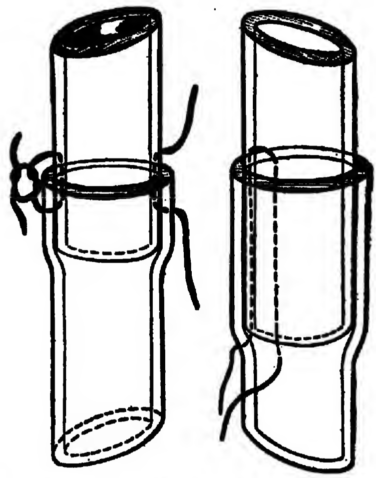
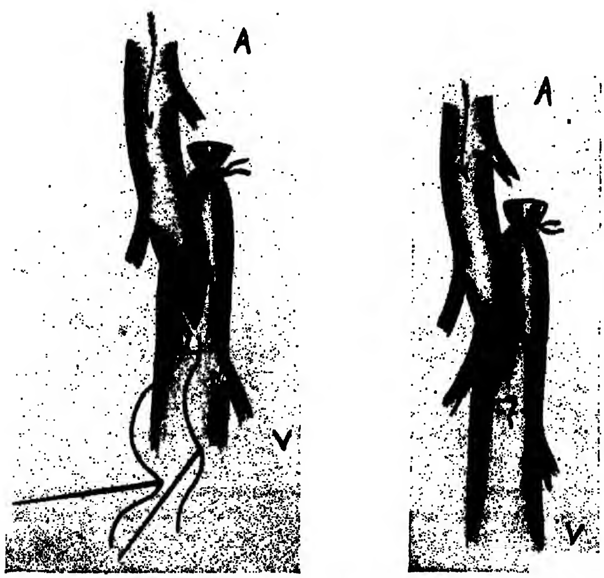


Fig. 44.—Bouglé's Invagination Method of Arteriorrhaphy.

than when the end-to-end or direct marginal anastomosis is performed. Nevertheless, invagination has been better understood and probably



Figs. 45, 46.—Arteriovenous Anastomosis by Lateral Implantation. Wieting's Method.

more frequently applied than any other method (up to and including 1906). Yet, obliterative thrombus formation results so frequently in

experimental work that its application clinically is fraught with grave doubts as to its ultimate success.

In justice to the method, it must be said that in 13 of the 24 cases of circular arteriorrhaphy, or end-to-end anastomosis, recently collected by Stitch, the anastomosis was established by Murphy's invagination or its modifications. In 7 of these 13 cases the results were satisfactory in so far as the preservation of the peripheral circulation was obtained, though it is quite uncertain whether thrombosis occurred at the anastomotic joint or not. In many of these, no doubt, the circulation was maintained by collaterals. Of the several modifications of the invagination method, that recently recommended by Wieting Pasha, of Constantinople, is worthy of special notice as a simple and successful method in arteriovenous anastomosis (Figs. 45 and 46). This method consists essentially in intubating or implanting the artery into the vein by a small lateral slit made in the vein after it has been ligated, so as to interrupt its central circulation. The procedure resembles Van Hook's method of anastomosing the ureters. In Wieting's case the reversal of the circulation was demonstrated and gangrene of the limb arrested.

Invagination Method.—J. B. Murphy's typical procedure. This method is applicable to all vessels of large caliber, including the popliteal and the femoral, in which not more than three-fourths of an inch have been removed by injury or excision. Possibly in the popliteal space, Scarpa's triangle, or in the axillary space, where the position of the limb can be made to relieve the tension of the vessel, it may be used after even a larger loss in length. As in all the methods of arteriorrhaphy, the points to be considered in the technic are:

(1) Complete asepsis; (2) exposure of the vessel with as little injury as possible; (3) temporary suppression of the blood current; (4) control of the vessel while applying the suture; (5) accurate approximation of the walls; (6) perfect hemostasis by pressure after the clamps are taken off; (7) careful toilet of the wound. After obtaining temporary occlusion of the vessel with clamps, the distal end of the artery is incised longitudinally for a short distance, and the proximal end is invaginated into the distal end, which has thus been prepared to receive it. In order to invaginate the vessels, two traction or invaginating sutures are applied on the proximal side, a short distance from the margin, and made to penetrate the walls of the artery except the intima. The free ends of the loop thus formed are threaded into separate needles, which are carried into the lumen of the distal artery and made to come out by perforating the walls at a short distance from each other. Three of these traction perforating sutures are placed around the vessel at equidistant points, so that, by making traction upon the loops, the proximal end can be readily and accurately invaginated into the distal end. After the invagination has been effected, the perforating traction loops are tied over the distal side and the joint is further secured by passing a few interrupted sutures (non-perforating) at the point of junction of the two vessels. (Modifications of this procedure have been proposed by Bouglé, Jensen, and others.)

Payr's Method of Circular Arteriorrhaphy with Absorbable Magnesium Rings, 1900.—This is a method of invagination in which an absorbable magnesium ring is used as a provisional support for the invaginated portion (intussusceptum), to keep the lumen of the vessel open until union has taken place. Payr's method as modified by Hoepfner is as follows: After exposing the artery to be

invaginated, the protected Hoepfner clamps are applied to each side of the injury (Fig. 47) at a sufficient distance from the seat of injury to permit of the free manipulation of the stumps after the injured part has been divided or resected. The connective tissue holding the ends of the stumps to the sheath is cleared carefully with toothless forceps, great care being taken to avoid injury to the intima or the vessel as a whole, by rough handling or otherwise, for fear of thrombus formation. The Hoepfner clamps when properly adjusted with just sufficient pressure to obliterate the vessel without compressing it may remain as long as three hours in situ without damaging the endothelium. After denuding or resecting the injured artery, any blood remaining in the stumps is to be gently washed off with saline solution. The vessel-wall is then grasped at its margin with very fine dissecting forceps and three silk sutures are carried on fine floss needles and the smallest thread, through the margin, at three equidistant points. While one stump of the artery is being treated in this way, the other is kept covered with a gauze sponge soaked in physiologic salt solution. Drying of the endothelium is thus avoided and excessive contraction of the vessel is also prevented. The three threads attached to the

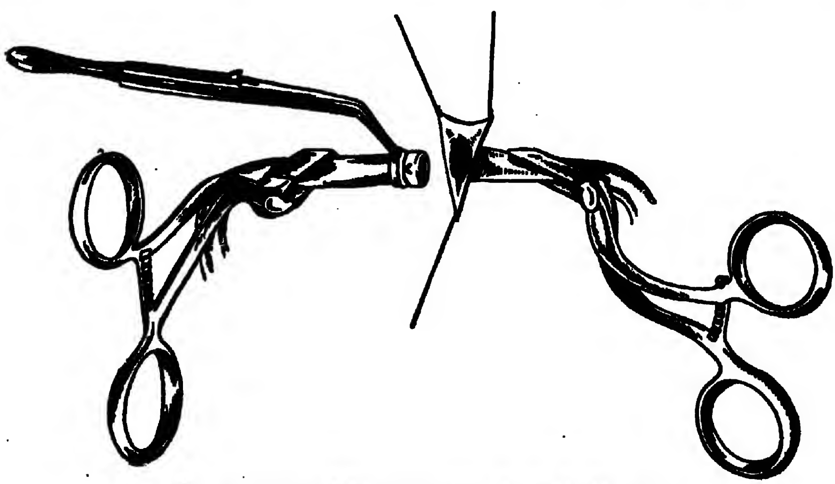


FIG. 47.—PAYR'S METHOD OF CIRCULAR ARTERIORRHAPHY.

proximal or cardiac end are tied to the margins and the long ends held together are passed through the magnesium ring, which is held in readiness on a special forceps (see Fig. 47). The ring is slipped, like a collar, over the vessel, after which traction is gently made upon the threads, and, as the ring is held steadily in the holder, the stretched cuff of the artery is rolled back and reversed sufficiently to cover the ring. The reversed cuff of the artery is then fastened to the ring by a fine, circular silk ligature which fits into a groove in the ring. The distal stump (intussuscipiens) is now stretched by traction on these threads and is drawn over the everted stump which contains the ring. Invagination of the distal into the proximal end is made secure by a final ligature tied over the whole joint on a level with the ring, after the invagination has been completed.

Hoepfner performed 28 experiments on the carotids and femoral arteries of dogs. He succeeded perfectly in obtaining circular anastomoses and in grafting detached sections of arteries from one part of the arterial system to the other. He was not able to obtain arteriovenous anastomoses without thrombosis. He was able to transplant the kidney to the neck by uniting the renal arteries and veins to the jugulars and carotids, leaving the ureter as a fistula in the neck. He implanted

successfully an amputated limb in one case out of three in which he tried the experiment. The magnesium rings absorb very rapidly; sometimes as fast as chromic catgut; they totally disappear in six months, leaving, however, gas cysts, as they are called, which result from the oxidation of the metal. The conditions for the successful application of this method are, that the artery shall not be resected for a greater length than 1 to 1½ centimeters, though Payr succeeded in approximating successfully a femoral vein after he had resected 4½ cm., but he could obtain the approximation only by keeping the thigh in a position of extreme flexion. The magnesium rings can be obtained in different sizes from the manufacturers, but the metal is so soft that it can be easily cut out of sheets and made into cylinders of the desired size. In transplantation experiments, in which the arteries of different

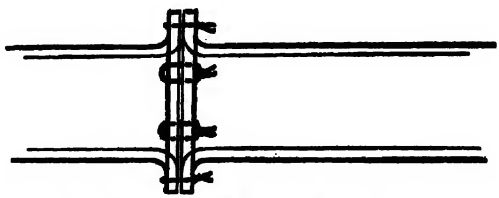


FIG. 48.—BRIAU AND JABOULAY'S METHOD OF CIRCULAR ARTERIORRHAPHY.

species of animal are brought together, thrombosis invariably followed in Hoepfner's experiments, but this is avoided by Carrel's technic. Payr's method has been adopted by Crile (with slight modifications) to simplify his method of direct blood transfusion.

Methods of Broad Marginal Confrontation.—The principle of confronting intima to intima over a broad surface of the everted margins of the cut artery, without invagination, was apparently suggested independently at the same time by Salomoni and by Briau and Jaboulay. Salomoni has experimented most extensively with this method with the aid of his pupils, Tomaselli, Funaijoli, and others. The same principle has been adopted by Jensen, who uses a U-shaped or mattress suture as originally suggested by Briau, and differing from Salomoni, who uses a simple interrupted suture.

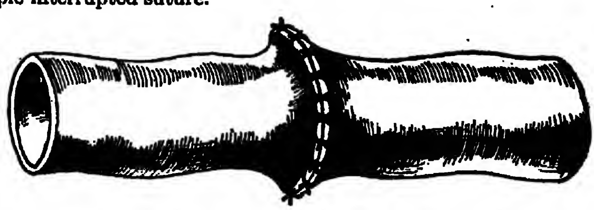


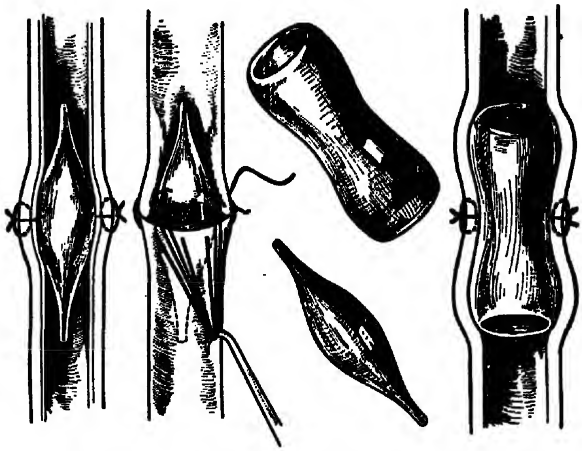
FIG. 49.—SALOMONI'S METHOD.

As the essentials of the technic are sufficiently explained by the illustrations (Figs. 48–50), we shall briefly refer to the modification of the same method by the latest contributor, Dorrance, of Philadelphia, who has described his procedure with marked precision and clearness.

Dorrance uses Pagenstecher's thread No. 1 on the finest sewing needle which will carry the thread. The hemostatic clamps are a limber-bladed forceps devised especially for this work. The suture is intended to be used for longitudinal, oblique, or transverse (complete and incomplete) wounds of the artery.

Fig. 51 shows the application of the method to a transverse wound of an artery. Dorrance has experimented chiefly on large animals, 9 horses and 5 dogs; in 7 circular anastomoses (50 per cent.) there was no thrombus. In 5 lateral sutures,

which were made in dogs, the lumen was preserved. There was one secondary hemorrhage. While this method has proved satisfactory in large animals, it is



A B
FIG. 50.—*A*, DE GAETANO'S METHOD, AND *B*, ABBE'S METHOD OF ARTERIORRHAPHY.

questionable whether the same technic could be as successfully applied in arteries of the size of the popliteal, in which the much more simple method of Carrel accomplishes perfectly satisfactory results.

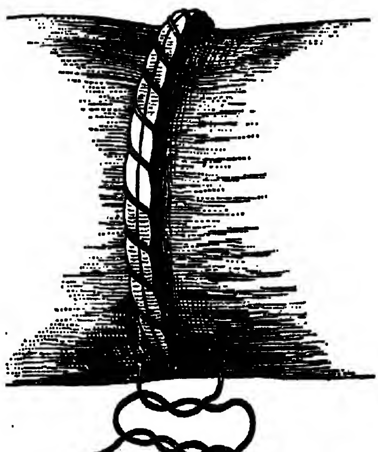


FIG. 51.—SUTURE OF INCOMPLETE TRANSVERSE WOUND. (Dorrance.)

Carrel's method of circular arteriorrhaphy is performed as follows:

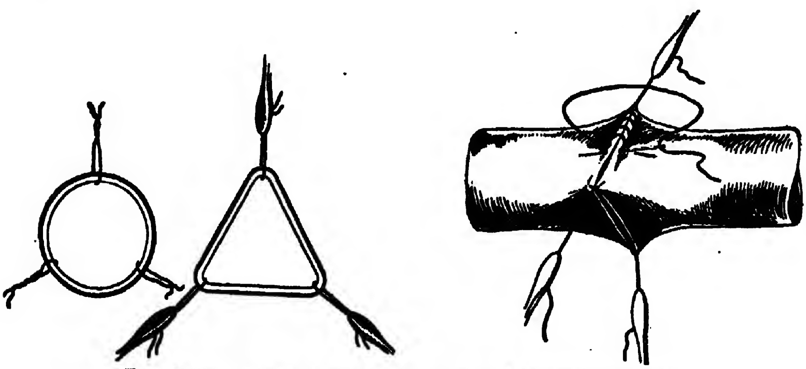
(1) Provisional hemostasis with elastic, flat clamps, well protected with rubber covers, or without rubber covers if Langenbeck's clips are used, Hoepfner's protected forceps (see Fig. 47) or Crile's will do well. Endothelial traumatism with toothed forceps must be avoided at all times under penalty of thrombosis.

(2) The two ends are brought in apposition.

(3) The traction loops, which are to convert the circular or oval outline of the cut arteries into triangular or prismatic surfaces, are introduced at equidistant points of the circumference, through the thickness of the margins, care being taken

to enter the intima as near the margin as possible. The needles are introduced from without inward on one margin and from within outward (from intima to adventitia) on the other. The loops of thread which have now transfixed the cut edges of the artery are tightened until the margins of the vessels are brought together and held, each separately, in the bite of a hemostatic clamp. The clamps are then turned over to an assistant, who, by making gentle traction, not only brings the two edges of the vessel together closer, but transforms the circular outline of the artery into a straight line between the lines of traction. By pulling gently upon the thread, even the small arteries will stretch sufficiently to permit a continued suture to be made securely and rapidly as each section of the triangle or prism formed by the traction of the loops brings each side to view.

By introducing the needle into the marginal edges of the vessel, the opposed surfaces of the intima are brought into perfect apposition and the threads are scarcely exposed to the contact of blood in the lumen of the vessel (see Figs. 52, 53). It is especially important that in carrying out this procedure, Carrel's instructions to use rigorous asepsis, the finest needles and the finest silk, as described under the technic of lateral arteriorrhaphy, and the care in lubricating the threads and the edges of the cut arteries with sterile vaseline should be strictly followed.[1]



FIGS. 52, 53.—CARREL'S METHOD OF CIRCULAR ARTERIORRHAPHY.

Since the advent of Carrel and the publication of his first American contribution in 1905 the scale of evidence has undoubtedly turned in favor of the simpler unaided methods of suture, and the Carrel technic has become the method of election at the present time. By the simple but extremely delicate technic which Carrel has devised, he has been able to accomplish almost incredible feats in uniting divided vessels by end-to-end anastomoses, even in such small vessels as the thyroid vessels of the dog. He has been able to transplant with almost unfailing success large sections of arteries and veins separately and by arteriovenous anastomosis to unite large vessels such as the aorta and the cava in the abdomen, thereby reversing the entire systemic circulation so as to throw the mass of the arterial blood from the aorta directly into the cava, and vice versâ. In a like manner he has reversed the circulation in the neck, transforming the jugular veins into arteries and the carotid arteries into veins; likewise, in the lower limbs, he has reversed the current so that the femoral vein became a pulsating artery and the artery a pulseless

[1] The recent and very interesting experiments on the suture and transplantation of arteries reported by Stich, Makkas and Dowmann, Leipsig, and by S. H. Watts, of Baltimore, and Sweet, of Philadelphia, and Faykiss, of Budapesth, not only confirm the experimental work of Carrel, but demonstrate the superiority of his technic.

vein. He has reversed the circulation in the thyroid arteries and veins and transplanted arterial and venous branches from one arterial trunk to another. He has been able to transplant the heart from one animal into the neck of another, uniting both carotids and both jugulars to the aorta, pulmonary artery, and pulmonary veins, obtaining such good union as to keep up the cardiac cycle in regular rhythm sufficiently for class demonstration and cardiographic tracings. He has transplanted kidneys with their vascular connections to the neck, and from one animal to another, surviving for days and weeks and secreting urine of almost a normal character. He has transplanted ovaries; made new blood-vessels out of peritoneum, etc. —experiments too numerous to relate, of a very suggestive and impressive character. At present these possess solely physiologic interest, but all are extremely important in demonstrating the efficiency of the technic he has devised. And the fact that he has been able to obtain these numerous anastomoses with almost unfailing success and without obliterative thrombosis is most impressive. The technic of Carrel or its modifications (Figs. 52–54) have been frequently applied clinically in the *lateral* suture of wounded arteries, but only eight instances of the *circular* or end-to-end application of this method to the living human subject are recorded in the literature (Goyanes, Lilienthal, Hubbard, Delanglade, Lexer, Martin, Braun, Stich). Of these the most conclusive success is that reported by H. Braun (Leipzic) (Arch. f. klin. Chir. Band 86, Hft. 3, 1908), in which a section of the abdominal aorta was removed in the course of the extirpation of an enormous ganglion neuroma of the sympathetic; the patient, a child of 6½ years, recovered without any circulatory disturbance.

FIG. 54.—LATERAL ARTERIORRHAPHY. Using the principles of Carrel's technic.

Indications for the Application of the Suture.—(1) The suture is indicated and should be applied in preference to the ligature in all longitudinal, oblique, or transverse wounds of the large arteries in the neck and at the root of limbs, in which the wound can be closed without obliterating the lumen of the artery. (2) In all complete divisions of these vessels, with a loss of substance from injury or resection, not exceeding ¾ inch. On these cases, however, the better rule is not to attempt a direct end-to-end anastomosis when the approximation cannot be maintained without overstretching or great tension of the injured vessels. (3) The suture is especially indicated in injuries of the common and internal carotid, the common femoral, the popliteal, subclavian, and axillary.

The importance of restoring the circulation in injuries of the internal and common carotid is made most apparent in adult and aged subjects on account

of the well-known dangers from secondary cerebral disturbances, hemiplegia, aphasia, softening of the brain, etc., which follow carotid ligation in spite of the most

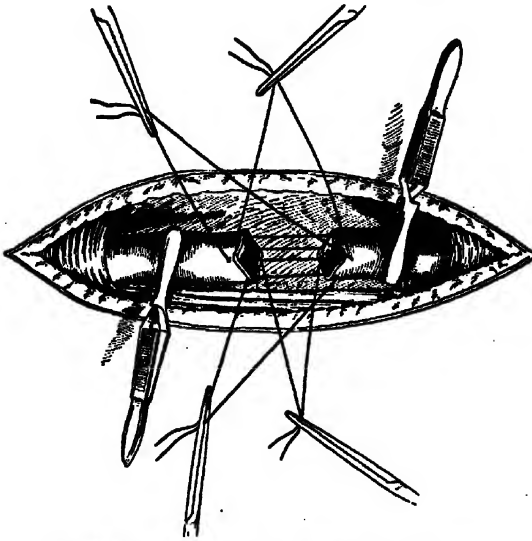


FIG. 55.—FROUIN'S METHOD OF ARTERIAL SUTURE.
The four points of approximation.

perfect aseptic healing (11 per cent., Lestelle, 1903; 24 per cent., Lebram, 1906). The internal carotid has been sutured twice successively, once by Glück and once by Garrè; the common carotid also by Seggel, Launay, Depage. Modern statistics

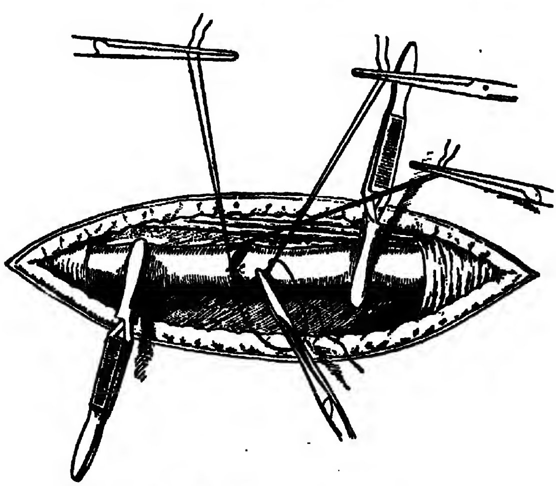


FIG. 56.—FROUIN'S METHOD OF ARTERIAL SUTURE.
The hem at the points of approximation.

show that gangrene follows in 19 per cent. of femoral ligations for trauma in civil life, and 21 per cent. in military practice (Raabe). The simultaneous ligation of the artery and vein is also more fatal to the life of the limb (60 per cent. in the older

statistics of von, Bergmann 48.3 per cent., Ziegler; 55 per cent., Steiner, 1897). The worst prognosis from the point of view of gangrene follows when the popliteal artery and vein are both injured or obliterated (54.5 per cent., Lejars, in ordinary injuries, and 100 per cent. in crushing injuries, Schorong). The simultaneous injury of both femoral artery and vein is likewise fraught with great peril to the limb when the ligature is applied (gangrene in 14 out of 24 cases, Niebergall (1893); 12 in 22 cases, Kammerer). Injury to both tibial vessels simultaneously is almost as certainly fatal to the foot. In the upper extremity the collateral circulation is so ample that the risk of gangrene is comparatively slight. Ligation of the subclavian is followed by gangrene in the hand and arm in 2.01 per cent.; after axillary ligatures, 6.6 per cent.; after brachial ligatures, 18.75 per cent., when applied immediately above the origin of the profunda. The axillary and the brachial have been sutured with greater frequency than the other arteries, probably on account of their greater liability to injury (axillary) in the extirpation of the axillary contents in operations for cancer of the breast. Suture of the vessels of the upper extremity has been performed with sufficient frequency to prove its practical value. In the abdomen,

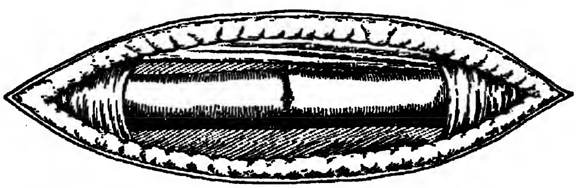


FIG. 57.—FROUIN'S METHOD OF ARTERIAL SUTURE.
The finished suture.

the abdominal aorta has been sutured three times successfully for injury in the course of an operation: once by Depage, of Brussels (1906), once by Berard and Cavaillon (1906), once by Braun (1907). The external iliacs, common and superficial femorals, and popliteals have been sutured a number of times for a variety of conditions apart from traumatism, with, as a whole, very satisfactory results, considering that the operators, in the majority of instances, have not had the benefit of the improved technic inaugurated by Carrel. (See, also, p. 133.)

(4) The suture is occasionally indicated after surgical incisions (arteriotomy) of the larger arteries and veins for the removal of septic or non-septic thrombi and emboli, which threaten the life of limb. In the 7 cases in which this has been tried (see Thrombectomy, p. 161) the incisions were completely closed with sutures after removal of the clot, the wounds healing without secondary hemorrhage.

(5) In the treatment of arterial and arteriovenous aneurisms, to close the vascular orifices in the sac by my own intrasaccular method, or after the resection of the sac, to close the opening left in the vessel.

(6) After the resection of arteries involved in certain neoplasms and aneurisms. In these cases the resected portion is too long to permit of a direct end-to-end anastomosis, but the adjoining vein may be made to act as a substitute if a section of the vein is transplanted between the severed ends of the artery without detaching it from its vascular surroundings (*partial venous transplantation of Carrel*, see Fig. 58). This has been done successfully in very recent cases reported by J. Goyanes (1906), popliteal aneurism; Erich Lexer

(1906), axillary aneurism; P. Delbet (1907), popliteal aneurism, the last two proving unsuccessful.

(7) Circular arteriovenous anastomosis has been tried in cases of threatened gangrene of the limbs from obstruction to the main artery, the object of the operation being to *arterialize* the vein so that the distal parts may be nourished and the gangrene arrested. This operation has been tried 13 times (San Martin, 2 cases; Jaboulay, 1; J. C. Hubbard, 3; H. Lilienthal, 1; Ballance, 1; G. Torrance, 1; Tuffier, 1; Ohran, 1; Doberauer, 1; Wieting, 1). Thus far, the results cannot be said to be therapeutically satisfactory except in Wieting's case, in which the reversal of the circulation was successfully obtained and the gangrene arrested.

The **suture is contraindicated**—(1) in all smaller arteries in which the collateral circulation is normally competent to maintain the nutrition of the limb after ligation; (2) in all crushed and lacerated

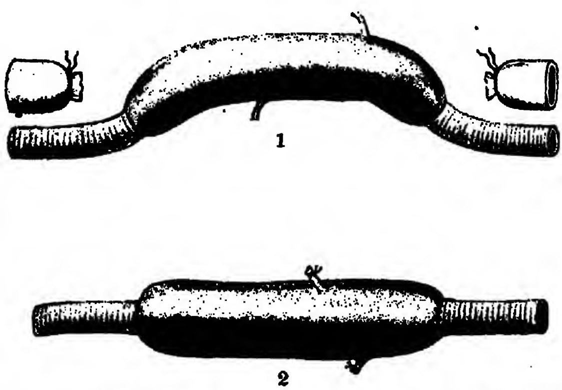


Fig. 58.—(1) Incomplete Biterminal Transplantation: (*a*) Femoral vein, isolated segment of the femoral vein, femoral artery. (2) Complete Biterminal Transplantation: (*b*) Carotid artery and transplanted segment of the external jugular vein. (Carrel and Guthrie.)

wounds and arteries in which all the perivascular tissues are irreparably or badly damaged; (3) in all suppurating or otherwise infected wounds, as thrombus formation and secondary hemorrhage will certainly follow an infection of the line of suture; (4) in all cases in which approximation of the divided ends cannot be obtained without overstretching and in which venous grafting or substitution is impracticable.

Repair and Regeneration of Arteries After Suture.—The repair which follows after an arterial wound has been properly sutured, either by lateral or circular arteriorrhaphy, is equivalent, ultimately, to a complete and perfect regeneration of all the histologic elements which enter into the formation of the arterial wall, the elastic and muscular elements being reproduced as perfectly as the baser elements, if the specimens are examined long enough (at least one hundred days in dogs) to allow the regeneration of the elastic and muscular tissue to be completed (de Gaetano, Faykiss). Clinical experience fully confirms the histologic possibility of the complete regeneration of the vessels. An

extensive inquiry made by myself has failed to show that any aneurisms have formed at the seat of a previous suture.

Patching and Plastering of Arteries.—In experimental surgery, wounds of arteries and veins have been closed by patching them with transplanted grafts taken from distant veins or arteries of the same or other individuals. This procedure has been applied in a variety of ingenious ways on the arteries of dogs and other animals by Carrel, and by Taddei and Mariotti on veins. Instead of living vascular patches or grafts, Dr. G. E. Brewer, New York, has suggested the plastering of wounded arteries with sterile adhesive plaster (zinc oxid plaster spread over thin rubber tissue). In 14 experiments performed on dogs, 6 were made with heavier plaster, and in all of these the vessel was occluded at the point of pressure. In all cases he applied the plaster without wounding the artery and yet thrombosis followed. In all, 5 successes out of 14 experiments were obtained. This mode of procedure is made sufficiently clear by the accompanying illustration (Fig. 59) not to require further description.

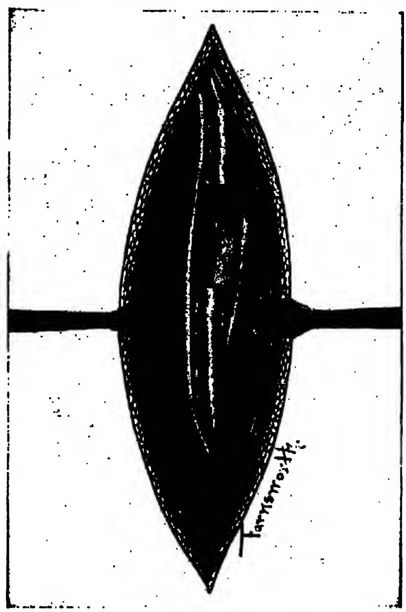


FIG. 59.—BREWER'S METHOD OF CLOSING ARTERIAL WOUNDS BY SPECIAL RUBBER PLASTER. (Bickham.)

The vessel has been surrounded by several turns of the rubber plaster, which is then cut transversely.

Note.—It is interesting to note that the idea of occluding wounded arteries by plastering or, at least, covering them with a protective material, as was done originally by Glück (1897), who used sheaths and patches made of animal and rubber tissue, by Dawbarn, who used a special glue, and by Brewer as above described, was anticipated and tried in a crude way by a medical student in Paris, Leconte, who wrote his thesis on his method in 1774. His procedure consisted in wrapping a section of thin goose-quill around the wounded vessel and holding it in place with a ligature, all of which he held in place and sealed with a varnish made of "turpentine and balm of Araeus." The quill sheath was removed after three or four days. The wound was always infected and the hemostasis which was obtained is now accounted for by thrombotic obliteration. (See Hist. Soc. Royale de Médicin de Paris, 1776.)

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SURGERY OF THE VEINS.

DISEASES AND INJURIES OF THE VEINS.

Preliminary Anatomic and Physiologic Data.—The veins, embryologically, are derivatives of the mesoblast and form part of the original germinal mass from which the blood-vessels, including the lymphatics and the great serous spaces, are ultimately differentiated in the embryo. The veins are continuations of the arterial system and, structurally considered, are identical with the arteries and lymphatics, except in so far as their structure has been differentiated to meet the requirements of their specific physiologic function. This *unity of the vascular endothelia* is of great importance in surgical practice, since the behavior of this membrane in the processes of repair and regeneration is everywhere the same when subjected to the same conditions of traumatism or disease. Hence, the plastic results so readily obtained by the approximation of serous surfaces in the peritoneum are to be expected in the surgery of the blood-vessels. Hence, also, the tendency to thrombosis and embolism is everywhere the same whenever the endothelium is injured or irritated in such a way as to destroy or impair its two-fold function, viz., the preservation of the fluidity of the blood and lymph and the uninterrupted continuity of the blood- and lymph-streams.

The veins, however, in spite of their close kinship to the arteries and the great similarity of their histologic structure, present marked differences, which give them a distinct anatomic and physiologic individuality. The veins, like the arteries, have three coats. The *internal* coat of the veins is the same as the internal coat of the arteries, forming the only coat which the capillaries possess, and is the intermediary link which continues the arterial into the venous system. The *middle* coat is composed of longitudinal and circular elastic fibers, interlacing with involuntary muscular fibers, both of which are, however, much less abundant than in the arteries. The *external* coat is formed chiefly of white fibrous tissue. The coats of the veins differ from the arteries in the thinness of the muscular coat and in the presence of valves formed by duplication or folds of the intima or serous layer in the superficial and in a few of the deep veins. The thinness of the muscular coat of the veins prevents them from having that rotundity, elasticity, and contractility which is so characteristic of the arteries;

it also permits distention or bulging of the vessels when there is some mechanical impediment to the free return of venous blood to the heart. To serve this purpose, the veins possess an inherent capacity of limited distention which is never acquired by normal arteries. This is of importance in connection with the study of varices; with the known greater adaptation of the veins to obstructive injuries, and also in the greater capacity of the venous collateral circulation. Notwithstanding the thinness of the walls of the veins, they are relatively as strong as those of the arteries. The total capacity of the venous system is estimated to be fully seven times greater than that of the arterial, and for this reason, after death, the entire blood-content of the arterial system is readily held by the veins after the arteries are emptied by the last systolic contraction and the final contraction of the arteries (Stimson).

The presence of valves is a peculiarity of veins. The valves support the blood mechanically. They are found in the superficial venous system and especially in the lower extremities. This point has an important influence upon the development of varices and other ectatic diseases of veins. While these valves are competent to resist the normal backflow of the venous current, they soon yield to a long-sustained pressure which is greater than the normal intravenous tension. Thus, in his notable experiments on the production of arteriovenous anastomosis, Alexis Carrel was able to obtain a total reversal of the blood-current, so that the veins became arterialized whenever the full arterial pressure was brought to bear against the valves by a direct end-to-end anastomosis with a vein. In this way the femoral and saphenous veins carried the arterial blood to the periphery, reaching the foot, and coming back as venous blood in the arteries. Under these circumstances, it has been shown by histologic examination that the veins become arterialized, not only in function, but in structure, and that the muscular and elastic coats of the veins become thickened and hypertrophied, thus resembling the arteries. This is a beautiful illustration of the law of physiologic adaptation of structure to function.

The collateral circuit by which the blood finds its way to the heart after the occlusion of the great venous trunks, especially of the lower limbs (femorals, iliacs, axillary, cava, etc.), is at first sight more difficult to realize than in the arteries where the progressive subdivision of these vessels and the high blood-pressure of the arterial system readily provide new routes for the arterial flow to the periphery when a main channel is obstructed. Abundant clinical demonstration and experimental evidence show, however, that the venous system is, nevertheless, sufficiently provided with collateral routes by which the blood reaches the heart, unless prevented by unfavorable conditions.

When these five conditions are present (especially when the integrity of the corresponding arteries is maintained), the collateral venous circulation is established and fatal peripheral stasis from obstruction to the main venous trunks is avoided. In addition to the great capacity of the anastomotic network and the peculiar structure of the venous wall,

which makes it capable of dilatation, the remarkable reproductive and regenerative capacity displayed by veins in rapidly forming new channels, as shown after the thrombotic obstruction of large veins by their reproduction over large areas after surgical phlebectomies, is also to be considered in accounting for the successful reëstablishment of the collateral circulation and the comparative rarity of gangrene in the peripheral parts whenever the veins alone become obstructed at the root of limbs and elsewhere.

PHLEBITIS.

Phlebitis is a word first applied by Breschet (1818) to designate the inflammation of veins. John Hunter was one of the first observers to associate the evil effects (septic phlebitis), which sometimes followed the old practice of venesection, to inflammations of the veins. Later came the notable contribution of Cruveilhier in 1834, who, striving to account for the constant association of thrombosis with phlebitis, concluded that the thrombus formation is always dependent upon a previous inflammation or injury of the veins. In this view he was contradicted by Virchow, who maintained that the phlebitis was always secondary to the clotting or thrombus formation in the veins. For years Virchow's views prevailed, but at present Cruveilhier's dictum that thrombus formation is, as a rule, secondary to structural disease of the endothelium in phlebitis is universally accepted (Bouglé). While it is evident that there are exceptions to this general rule and that thrombus formation may precede the development of the phlebitic process, or the degenerative changes in the endothelium, with which thrombosis is always associated, it may be said that this statement applies to all forms of septic phlebitis in which the inflammatory or degenerative process is started by the direct deposition of microorganisms in the intima by the blood-stream, or by contact with irritant poisons contained in the blood itself. In this respect septic phlebitis differs markedly from the septic arteritis, the inflammation beginning in the latter more often as an embolic thrombo-arteritis, caused by the detachment of a septic fragment, set free from the heart chambers or their valves, the embolus becoming lodged in some peripheral artery, where it starts a secondary and septic arteritis. Again, it must also be recognized that in consequence of the sluggish circulation of the veins, in the lower extremities particularly, thrombotic clotting may occur as a primary factor, especially in the constitutional diseases in which hemolytic processes are going on with great liberation of agglutinins from the disintegrating corpuscles; it is also possible for colonies of microörganisms to become localized in sluggish areas of the circulation and cause coagulation by the ferment-like action of their toxins before an actual or appreciable alteration has been started in the endothelium. This must be a very exceptional occurrence, however, and it may be safely asserted that thrombus formation rarely occurs in the venous system without a primary injury or disease of the endothelium as a determining factor.

Phlebitis, with its associate thrombosis, is a far more frequent pathologic process than the corresponding lesion of the arteries. This is readily accounted for by—(1) The greater thinness and permeability of the venous coats, which allow the microörganisms to penetrate them more readily; (2) by the comparative sluggishness of the venous circulation in the peripheral parts; (3) by the superficial and more exposed distribution of the veins in the subcutaneous areas, which subjects them to more frequent obstructions from injuries and extraneous causes; (4) by the greater coagulability of the venous blood.

Classification.—In a general way phlebitis may be subdivided into: (1) Aseptic; (2) toxic; (3) septic. *Aseptic* phlebitis is characterized by the limitation of the local tissue changes involved in the process of repair and regeneration, and is, therefore, not, surgically speaking, inflammatory. The term phlebitis is, therefore, scarcely justifiable in such cases.

Toxic Phlebitis.—The word aseptic has also been used to distinguish certain non-purulent forms of phlebitis of obscure etiology, in which there are unmistakable degenerative changes in the endothelium, if not positive inflammatory signs, and of which venous thrombosis is an unfailing accompaniment. In these cases the process resolves itself without suppuration and without any clinical or bacteriologic evidence of direct microbic infection. In this group the presumable cause of phlebitis is a toxinemia, caused by the presence in the blood of autogenic and metabolic poisons or of heterogenic toxins; these acting as irritants (amboceptors, Ehrlich) cause destructive changes in the protoplasm of the cells, which favor thrombus formation. These degenerative structural changes may, for convenience, be classed as inflammatory, though they are never associated with the violent leukocytic reactions which characterize the true inflammations (Grawitz). Gouty, rheumatic, chlorotic, cachectic, and many of the aseptic postoperative thromboses are examples of this group.

Septic, Non-pyogenic Phlebitis.—On the other hand, there is a large group of phlebites which develop in the course of infectious diseases as an intercurrent infection, which also resolve in a benign way after going through a non-purulent course. In this group the degenerative or inflammatory changes which go on in the inner coat of the vessel are also of toxic origin rather than of direct bacterial etiology. But as the toxinemia is dependent upon bacterial activity (toxins, toxalbumins, etc.) and upon the presence of pathogenic (not pyogenic) cocci, which may have colonized in some parts of the organism outside of the seat of the phlebitis (not essentially dependent upon autogenic poisons, as in the toxic type), we should group these, for convenience, under the general title of septic non-pyogenic phlebitis. This group includes probably the majority of the phlebites which occur in the course of the general febrile infections, typhoid, typhus, pneumonia, the exanthemata, influenza, appendicitis, and in other postoperative states.

Septic pyogenic or purulent phlebitis is the second and most formidable division of this septic group. It is essentially dependent

for its causation upon the localization and colonization of pyogenic micro-organisms (staphylococci and streptococci) in the venous walls, thus accounting for the great tendency to migration and metastasis displayed by infections of this type. The most notable examples of this group are the progressive and purulent phlebitis of the lateral or sigmoid sinus consequent upon middle-ear disease; in the especially malignant type of facial thrombophlebitis caused by carbuncles and furuncles of the upper lip, the disease spreading rapidly through the ophthalmic veins to the cavernous sinus, thence to the meninges and the brain; in pyelophlebitis or portal phlebitis after intestinal, peritoneal, and especially appendicular infections; and as a sequel of virulent ulcers, abscesses, and wounds of the lower extremities. In all these forms of phlebitis, excluding the strictly aseptic type, progressive purulent thrombosis occurs in the veins—hence the term thrombophlebitis, which is used synonymously with phlebitis, because of the universal association of blood-clotting with the infectious lesions of these vessels.

The prefixes *peri-*, *meso-*, and *endo*-phlebitis are applied here as in arterial pathology, to distinguish not the limitations of the inflammatory process or the infection to either one of the three coats of the artery, but to accentuate or indicate the starting-point of the process and the seat of the most marked lesions. All forms of phlebitis invariably involve all the tunics and reach the endothelium or the intima, either as an initial or a terminal process. In all the toxic and non-pyogenic forms the process, as a rule, is started in the endothelium as an endophlebitis (typhoid, typhus, pneumonia, gout, the exanthemata). In the acute pyogenic forms the process begins as an endophlebitis, even when metastatic abscesses are created by migratory pyogenic emboli in the lungs, liver, spleen, kidneys, etc., from fragments of originally autochthonous septic thrombi. Often, however, the purulent phlebitis is initiated in the adventitia as a perivenous infection by direct inoculation with septic organisms contained in neighboring purulent foci (sigmoid sinusitis, in middle-ear disease, phlebitis in appendicular abscess, phlebitis in acute phlegmon of the neck). In other instances, the nature of which is still under investigation and in which the pathology of the phlebitic process lies on the border-line between degeneration and chronic inflammation, the media is apparently the seat of the initial lesion. This is the group of the phleboscleroses (analogous to the arterioscleroses), in which the lesion insidiously attacks the muscular and elastic tunics of the media and gradually involves the intima, leading then to atheromatous and thrombotic deposits in the veins and proliferative changes in the endothelium, which contract the lumen of the vessel (varicose veins).

In accordance with the duration and extent of the inflammatory process, phlebitis may be *acute*, *subacute*, or *chronic*, *partial*, *circumscribed*, or *diffuse*.

John Hunter classified phlebitis into three clinical types: (1) The adhesive or plastic forms; (2) the suppurative or purulent form; and (3)

the ulcerative form. This classification has remained classic almost up to the present time. Hunter could not conceive of any so-called aseptic form; his plastic form is included in our toxic non-pyogenic septic forms; his suppurative form is our pyogenic septic form, and his ulcerative form is merely a derivation of the diffuse type of our present circumscribed purulent or pyogenic phlebitis.

Etiology and Pathogenesis.—The etiology of all forms of phlebitis, with the exceptions previously mentioned, is inseparably linked with microbic infection and the autogenic toxic processes involved in certain forms of perverted metabolism (gouty rheumatism). The toxic or septic form, with which we are especially concerned, is associated with the presence of the pyogenic organisms, staphylococci, streptococci, pneumococci, bacillus typhosus, bacillus tuberculosis, the micro-organisms of the exanthemata, of syphilis, and other genera. Phlebitis spreads most frequently by direct continuity of surface, as in the malignant thrombophlebitis of the facial veins following furuncle or carbuncle of the upper lip; after operations upon hemorrhoids and other rectal diseases, which involve the hemorrhoidal plexus, and in appendicitis, when the septic phlebitis spreads to the portal radicles and ends as a portal thrombophlebitis; in intestinal ulcerations the phlebitis spreads to the mesenteric plexus, causing mesenteric thrombosis and obstructive gangrene of the intestines. The same process is observed in some forms of puerperal pelvic infection or after operations upon the uterus and adnexa, in which the infection spreads in the direction of the blood current from the uterine cavity or walls to the veins in the broad ligaments, thence to the external iliac and femoral veins.

Metastatic Phlebitis.—Again, in other instances in which the phlebitis is started at a distance from the original focus, the "leap" from the primary focus to the seat of the phlebitis can only be accounted for by metastasis, as when the infection introduced in a dissecting-room puncture of the index-finger is followed by a thrombophlebitis of the femoral veins (Charcot), or, conversely, when an infected wound of the knee is followed by a phlebitis of the jugular and subclavian veins (Quénu). Such "leaps" at a distance can only be accounted for by the fact that the infecting bacterial colonies have entered the venous stream and have succeeded in filtering through the pulmonary plexus, or through the direct communicating channels described by Webber, which allow an embolus to travel directly from the pulmonary artery to the venous radicles in the lungs, etc. In this and other ways an embolus may find its way directly from the right to the left side of the heart and engage in the arterial circuit. In ascending abdominal affections from the peritoneal and portal tributaries the path of the infection may be, as shown by Retzius and Bernard, by the portal radicles directly to the vena cava, through the liver, and through the capillaries of this organ, which are wider than those of the lung (Gerulanos), and, therefore, are pervious, not only to bacteria, but to minute emboli.

Mixed Infections.—It often happens that in the course of many infections of non-pyogenic character, typhoid, typhus, etc., secondary

infections occur in which the staphylococci and streptococci play a leading part and cause acute types of phlebitis, which are in no way connected etiologically with the original disease. *Mixed infections* of this character are also met often in puerperal phlebitis, in which the gonococci combine with the pus-cocci in creating the most formidable septic disturbances. As in all infections, it is important to bear in mind, in the pathogenesis, that traumatism or disease involving the veins will always be a powerful factor in favoring the localization of a general infection or determining the regional distribution of the phlebitic process.

Thrombosis.—Whether the phlebitis begin as an *endo*-phlebitis or a *peri*-phlebitis, the immediate primary effect of the contact of the micro-organisms or their toxins with the endothelium of the vessels is to produce certain definite changes in the protoplasm of the cells, which lead to the coagulation of the blood and the formation of thrombi. (For the consideration of Thrombosis, see Vol. I., p. 418.)

Embolism.—The most serious and dreaded complication or sequel of thrombosis is embolism. (For consideration of Embolism, see Vol. I., p. 444.)

Symptomatology and Clinical History of Phlebitis.—The toxic, attenuated, non-pyogenic forms and non-traumatic varieties of phlebitis occur most frequently and typically in the lower extremities, where they have been recognized and described from time immemorial under the name of *phlegmasia alba dolens*—a term which is applied at the present time not only to the post-puerperal type of thrombophlebitis, but to the forms observed as sequelæ or intercurrent complications of abdominal operations and the infectious diseases. Usually the left lower limb or leg is the preferred seat of the affection for reasons explained in dealing with post-operative thrombosis (see chapter on Thrombosis and Embolism, Vol. I., p. 437).

The period of invasion is characterized by disturbances in temperature, fever, malaise, chilly sensations, rigors—often so slight that they may pass unnoticed. Attention to the limb is attracted by pain which never fails (hence the adjective dolens). The pain may be dull or acute, is usually aggravated by the least motion and by pressure along the line of the deep and superficial vein. The limb becomes edematous from the foot to the thigh, though this is variable.

While edema is almost an invariable accompaniment of venous thrombosis, its presence is by no means easily accounted for. Boddaert has shown experimentally that the femoral at Poupart's ligament and even the iliac may be ligated, without edema, as long as the lymphatics are not included. When the main lymph-channels are also involved, then edema invariably follows. The association of phlebitis with lymphangitis, the extent of the thrombus in the vein, and the propagation of the thrombotic process along important collaterals account for the different behavior of phlebitic inflammations in regard to the edema.

Usually when there is edema the skin is tense, white, and shining, and does not pit much on pressure. The inguinal glands enlarge, the limb feels heavy and numb; there is a hypoesthesia to the touch, which

contrasts with the acute sensibility of the veins. Paresthesia is often observed, which is due to coincident peripheral lesions of the nerves (Klippel) or to phlebitis of the intrasciatic or venous plexus of the crural nerve (Quénu). On palpation, the diagnosis is confirmed by feeling the hard, swollen, rigid, tender cords along the line of the superficial veins, and less distinctly if the deep veins are involved. The affected leg is a little warmer than the other. Later, trophoneural disturbances, muscular atrophy, purpuric eruptions, and permanent alterations in the skin set in. The skin also often presents a streaked or marbled appearance, which is strikingly in contrast with the pallor and whiteness of the surrounding skin. The muscles of the calf contract and the foot becomes extended, assuming, in long-standing cases, an equinus or equinovarus attitude.

In the milder types of phlebitic phlegmasias, the symptoms may all disappear in a few days and attract little or no attention. When the deep veins are involved, the swelling and pains as well as loss of control may continue for weeks or even months. The phlebitis may relapse by the successive invasion of new territory, each invasion being characterized by rigors and some elevation of temperature. The inflammation sometimes extends across from one iliac vein to another, forming what French authors designate as the "horseshoe" type of iliofemoral phlebitis. This is always a serious complication, as it completely disables the patient and compels the horizontal decubitus for an indefinite length of time. Hence, the frequency of bed-sores from direct pressure and defective nutrition (Bouglé).

One peculiarity that must be remembered and which distinguishes the venous from the arterial thrombi is the absence of any tendency to gangrene of the peripheral parts as a result of the venous obstruction.

Purulent or Pyogenic Phlebitis.—*The Limited or Circumscribed Type (with Pyemia).*—This differs essentially from the non-pyogenic and toxic varieties above described by the intensification of all the local and constitutional signs and symptoms, and the greater acuteness and rapidity of the process. When the phlebitis originates in a septic wound, an inflamed ulcer, carbuncle, or acute phlegmon, the advent of phlebitis is recognized by a train of signs and symptoms which usually point to a joint involvement of lymphatics and veins (acute phlebolymphangitis). Pain is at once felt in the limb along the track of the inflamed veins. The overlying skin becomes hot, red, and tender, and the lymphatic nodes in the groin swell; there is marked edema, but the inflamed venous cords can be readily felt. The constitutional disturbance is marked: rigors and high temperature (103° to 105° F.) of a remittent or intermittent type, followed by profuse sweats. The general condition, facies of anxiety, dry and parched tongue, delirium, and general distress, at once direct attention to the infectious nature of the trouble. The contrast between this angry inflammatory condition, with its red and inflamed skin and high fever, and the white, sometimes cold, marbled skin, of phlegmasia alba dolens, with its mild pyretic reaction, is most striking. The leukocyte count will show a marked

increase in the polynuclear and blood-plate count, as is the case in all the pyogenic processes, contrasting in this way also with the phlegmasia types, in which there is a comparatively low leukocytic reaction. The local signs in a few days tell of the progressive tendency to suppuration by the deep infiltration and edema over the inflamed veins. Areas of softening soon develop, fluctuation is felt in one or several places along the line of the vein, and periphlebitic abscesses will discharge spontaneously or can be evacuated by incision. The pus is reddish, grumous, and thick. In some cases, in which the infection is less virulent or the resistance of the tissues greater, the endophlebitic foci of suppuration may be multiple, but they will appear as small circumscribed collections arranged in longitudinal series, suggesting the appearance of a chaplet strung on a thread. In these cases, if the vein is excised, the entire string of abscesses may be enucleated *en masse* with the vein. These are the more favorable cases, in which the process is limited and the prognosis more favorable. They contrast agreeably with the *diffuse pyogenic variety*, in which the thrombus quickly breaks down and softens into a purulent mass which is soon disintegrated and swept into the circulation. This type is more often met in the jugular tract, as a result of lateral sinus thrombosis from middle-ear disease, or in carbuncles of the lip and face, which spread along the facial and ophthalmic vein to the sinuses and meninges of the brain. The clinical picture is then that of an acute, rapidly progressive septicemia. The patient may die in a few days or even hours, totally overwhelmed by the intensity and diffusion of the toxins, or if he survive long enough will succumb ultimately to exhaustion, marasmus, and a chronic pyrexia of a hectic type, consequent upon the succession of metastatic abscesses which develop from multiple pyogenic infarcts in the lungs, liver, kidneys, brain, heart, the serous cavities, and the joints.

Diagnosis.—The diagnosis of phlebitis is, as a rule, simple and unmistakable. Lymphangitis is frequently associated with the process, especially in the acute pyogenic variety. The association with lymphangitis always exaggerates the edema, the redness of the skin, and the enlargement of the glands. In some of the varieties of toxic phlebitis, the local signs, often marked externally by a normal appearance, may be confused with those of muscular rheumatism and even with periostitis. Sometimes, the first suspicion of the existence of phlebitis is only roused by the occurrence of symptoms of embolism in the pulmonary tract or in the internal organs. As a rule, the diagnosis of phlebitis, when we bear in mind the clinical history previously given, is easily established.

Prognosis.—Phlebitis, of no matter what kind, is always a source of grave concern, more especially in the pyogenic forms. Its dangers must never be overlooked, even in the mildest cases, or in the most aseptic interventions on the veins. Even after apparent complete recovery, death may occur suddenly from displacement of a clot. P. Merklen (1900) has called special attention to this class of cases in which fatal pulmonary embolism has occurred weeks and even

months after apparent recovery from phlebitis. In the acute diffuse pyogenic form in the neck and large venous trunks, the prognosis is almost invariably fatal.

Treatment.—The treatment of phlebitis may be classified into *preventive* and *curative,* the latter being subdivided into (*a*) *general,* symptomatic or constitutional, and (*b*) *local* or surgical.

The **preventive** treatment is summed up in the word "**asepsis.**" The influence of asepsis in wounds has completely revolutionized surgical practice, and the old fatal types of pyemia and septicemia, which depended upon a primary septic lymphophlebitis, have now practically vanished. Septic and pyogenic phlebitis still remains as a consequence of accidental wound contaminations and as a penalty for the neglect of surgical cleanliness. There are also several special groups of phlebitis which prevail in consequence of constitutional and unavoidable endovenous infections, against which there is little or no available method of prevention. In the lateral sinus infections of otitic origin and in the postoperative group certain precautions, especially in maintaining the asepsis of the auditory canal in the former, and avoiding unnecessary trauma as well as maintaining rigorous asepsis in the latter, may be regarded as the only available means of preventing phlebitic complications. Preventive treatment, by the use of internal remedies which diminish the coagulability of the blood, such as Wright's citric acid treatment, is recommended as a preventive of thrombosis in the terminal stage of the great infections (typhoid, typhus, the exanthemata, etc.), in which the tendency to coagulation is increased. This mode of treatment will always be of very restricted value, because it does not counteract the primary cause of the thrombus formation, which lies in some form of toxinemia of combined exo- and endogenic origin. An effective or abortive treatment should consist, theoretically, in the prompt administration of a reliable antitoxin of a polyvalent type, which could at once neutralize or inhibit the further growth of the bacteria in the veins or elsewhere. The anticipation caused by the success of diphtheria antitoxin has not yet been realized in connection with the streptococcal and staphylococcal infections, in spite of the efforts made to procure reliable antitoxic sera. But it is only in this direction that we may expect to prevent, abort, or arrest the progress of the infections which are the cause of the most fatal types of thrombophlebitis.

The **curative** treatment may be *constitutional* or *symptomatic, local* or *surgical.* The *constitutional treatment* is directed to the removal of the general cause, if possible, as in the gouty, rheumatic, syphilitic, and chlorotic cases; beyond this, there is no specific treatment. The antistreptococcal and staphylococcal sera are usually prescribed in the diffuse septic forms, but thus far more as a forlorn hope rather than with the expectation of accomplishing any definite results. The same unfavorable experience has attended the administration of the silver salts (Créde) by inunction or by intravenous injection of collargolum. Nothing can be said in special favor of the intravenous injection of anti-

septic substances (formalin solutions), nitrate of silver, or bichlorid of mercury, all of which would tend to do harm in the treatment of phlebitis by a decided hemolytic action which would favor thrombus formation without compensatory bactericidal action.

Symptomatic treatment, on the other hand, is always indicated to diminish pain, to support and strengthen the circulation, and to favor elimination. The main reliance is to be placed upon the *local treatment*, combined with good nursing, appropriate food, and moderate stimulation. The local treatment is summed up in the following indications: (1) Immobilization and absolute rest of the affected limb; (2) elevated position of the foot of the bed or of the limb to favor the drainage of the venous current toward the trunk. It should be covered with cotton batting, and bandaged over a padded gutter-splint of cardboard, extending from the foot to the thigh to immobilize the knee. In the superficial inflammations with much redness and heat an even layer of any of the kaolin mixtures may be applied between thin layers of gauze, like an antiseptic poultice, over the entire extremity and especially over the inflamed parts. A saturated watery solution of ichthyol, painted over the entire surface, will also prove decidedly beneficial in cases complicated with lymphangitis. Unguentum Crédé, mercurial ointment, and so-called local resolvent lotions have been recommended and applied, but none of these can compare in their beneficial effect with kaolin poultices, with or without ichthyol, or the liberal application of broad compresses, thoroughly saturated with a weak lead-and-opium lotion, which acts not only as a local astringent, but as a marked sedative. Immobilization and rest should be maintained for a month or more. From this extreme conservatism the pendulum of professional opinion is now swinging in the opposite direction—*i. e.*, toward applying early passive movements when the signs of the acute infection have passed, as shown by normal temperature, a subsidence of the edema, and softening of the hard venous cords. At this stage we recommend gentle passive movements of the joints and tentative surface stroking (effleurage) at a distance from the lines of infection, in order to improve the nutrition of the limb and activate the sluggish circulation. Massage is dangerous, and should not be attempted until months after complete convalescence has been established.

The **operative treatment of acute septic thrombophlebitis** has in view three indications, and the procedures adopted must vary according to these: (1) Ligation of the vein between the thrombotic focus and the uninfected vein on the cardiac side, in order to obstruct the further advance of the infection, and thus prevent the entrance of septic emboli into the circulation; (2) removal of the primary focus of infection, either by (*a*) direct incision into the vein, evacuation of the septic-thrombus and drainage, or (*b*) by the extirpation of the infected veins with the contained clot and its septic contents.

These principles have been extensively applied to the treatment of phlebitis already complicated by pyemia and septicemia, or in which

these dreaded complications were anticipated. The older surgeons, who had to contend with septic phlebitis much more frequently and disastrously than the surgeons of the modern period, fully realized the advantages of protecting the circulation by putting obstacles in the way of infection, but the septic methods at their command often aggravated the evil by adding further infection as a result of their procedures. In this way the practice of prophylactic ligation, thrombectomy, and phlebectomy in septic phlebitis fell into disrepute, and it is only in the Listerian period that surgical intervention again boldly asserted itself, and, in contemporary practice, has accomplished in this field some of its most brilliant achievements.

The greatest progress, however, has been accomplished in the treatment of the *endocranial sinus infections* of otitic origin, since Zaufal (1880) and Horsley (1886) first proposed the direct drainage and thrombectomy of the lateral sinus combined with the prophylactic ligature of the internal jugular. The first operation on these lines was performed by Arburthnot Lane (1888), followed shortly afterward by Ballance and Makins and a host of others. Not satisfied with the simple drainage of the lateral sinus at the mastoid, later operators (Lambotte, Chipault) have gone further in arresting the progress of the infection to the other sinuses by ligating the lateral sinus close to its origin at the torcular Herophili, Vidal (1901) actually *resecting* the lateral sinus from its origin to the mastoid in order to better control the infection. Macewen has successfully attacked the superior longitudinal sinus three times for septic phlebitis.

The conquests of surgery in the infections of the dural sinuses and in the treatment of phlebitis of the extremities have stimulated surgeons to invade other and, up to quite recently, forbidden territories. Of these, *the operative treatment of puerperal septic thrombophlebitis* is a notable example. This recent acquisition has been developed chiefly through the advocacy of Trendelenburg. Suppel (1894) was the first to suggest that in doing hysterectomy for puerperal pyemia the adjacent thrombotic veins should also be removed. Freund (1896), Bumm, and Trendelenburg were the first to act on this suggestion. The thrombosed and infected utero-ovarian and internal iliac veins are ligated either by the intraperitoneal incision of Bumm or the extraperitoneal method of Trendelenburg. Thus far, 20 cases have been reported from the clinics of Freund, Trendelenburg, Michel, Bumm, Hackel, Opitz and Friedmann (Faix), of which 13 died and 7 recovered—a heavy mortality, it is true, but when we consider that 85 per cent. of this class of patients die when treated by non-surgical methods (Bumm), the results of these pioneer efforts are not altogether discouraging.

The successful interventions of surgery in thrombophlebitis of the mesenteric veins and portal radicles, complicated with gangrene of the intestines, have also gradually increased since the surgical importance of thrombotic and embolic obstruction of the mesenteric vessels was first pointed out by Deçkart (1900). Brunner, in the latest publication, has collected altogether 89 cases of venous thrombosis, 32 of which

were operated upon, with 5 recoveries, including his own case. Adding to these 2 more cases, which recovered after operation for arterial obstruction, there are 6 recoveries recorded out of 57 operations. Considering the absolute certainty of death without operation, the disproportion between the recoveries and death is not so appalling.

VARICOSE VEINS; PHLEBECTASIS; VENOUS VARIX.

Varicose veins is a term applied to designate a permanent dilatation of veins due to changes in their walls. If the term phlebectasis is used to distinguish the cylindrical, fusiform, and tortuous (cirsoid) dilatations, the name varix may be restricted in its application to the circumscribed, sacculated dilatations in which pouches are formed by the venous walls, separated by constrictions or irregular narrow intervals (Kauffmann). The manifold transition forms, however, have led to the use of both words as synonymous terms.

Etiology.—The causes of varicose dilatation in veins are various. Sometimes the condition is congenital. In these very exceptional instances the varices are in the upper extremities and are unilateral. It sometimes has been seen in the lower extremity. A congenital malformation or a dystrophy, involving the elastic and muscular layers of the veins, can alone account for this state.

Predisposing Causes.—*Age.*—Miller found that in 108 operative cases in Halsted's clinic the varices appeared in one-third of the cases before the thirtieth year and two-thirds before the fortieth. *Sex.*—Males are more often affected than females (57 per cent. males; 43 per cent. females). *Pregnancy* exercises an influence independent of the mere mechanical interference of the gravid uterus with the pelvic veins, as varices often appear in the legs in the first months of gestation. If an abortion occurs, the varices will often disappear. *Arteriosclerosis* is undoubtedly an important factor and, in fact, the varicose process itself is distinctly of a sclerogenic character, corresponding to the same process in the arteries. *Nervous diseases* in which there is a loss of vasomotor control. *Chronic phlebitis*, which produces structural changes in the venous walls.

Exciting, Determining, or Localizing Causes.—One is the anatomic and physiologic conditions peculiar to the venous distribution in certain regions. Thus the frequency of varicose veins in the lower extremities (in 108 operative cases Miller found the right leg involved 21 times; the left alone, 25 times, and in 74, both limbs) is accounted for by the hydrodynamic influence of gravity in the erect posture. The lack of perivascular support in the saphenous and other superficial veins; the interference with the return flow by the constantly repeated contractions of the deep muscles and the aponeuroses of the calf; the weakness and often congenital deficiency of the valves; occupations which compel the erect posture, combined with hard labor (washerwomen, cooks, laborers, clerks, etc.), and, in fact, all conditions which favor venous stasis and strain the valves (trauma-

tism), thereby increasing the intravenous tension (Trendelenburg), determine the localization of the process in certain regions, more especially in the lower extremities, rectum, spermatic cord, etc.

But, in addition to this mechanical factor, there are other elements which must be considered as necessary to the pathogeny of the process. By forcing the valves, the mechanical factors may lead to chronic degenerative changes which destroy the elasticity of the veins, bringing about a compensatory phlebosclerosis. At other times a true phlebosclerosis lays the foundation for the venous ectasis, and this is more probably the fundamental trouble in the majority of cases.

Histologic changes observed in the walls of the varicose vein show that the primary and essential lesion is seated in the media, as in arteriosclerosis. There is first a marked thickening with hypertrophy of the muscular and elastic elements in the veins to compensate for the increased intravenous tension. Then follows the atrophic stage, in which the muscular and elastic elements gradually disappear. This change is particularly well observed in the saphenous veins, which are normally provided with an unusually strong muscular coat. The walls are ultimately transformed into fibrous inelastic tubes, which, yielding in places, lead to the pouching or sacculation of the walls. The valves also become atrophied and are reduced to fibrous stumps. The fibrosis spreads from the veins to the perivascular sheath and connective tissue, causing adhesions of the affected vein to its surroundings. In some parts of the vessel this proliferation of the intima is so great that the lumen of the vessel is often obliterated. When thrombosis occurs, calcic infiltration is likely to follow, and in this way venous calculi or phleboliths are formed. The varix, which may gradually attain the size of a hen's egg, becomes a blood-cyst through strangulation at its base. Large tortuous veins frequently intercommunicate, as the tortuous walls and pouches blend with each other at points of contact and are perforated as the result of pressure atrophy (anastomotic varix). The effect of this phlebosclerotic process is to elongate the veins, as sclerosis does the arteries. In the veins this elongation is much more marked as the vessels become much more tortuous and convoluted, owing to the lesser resistance and thickness of their walls.

Secondary Lesions.—In the vicinity of the varicose veins changes are observed in the adjoining arteries (sclerosis), in the nerves (interstitial or perineural fibrosis, Quénu), the varicose process also attacking the veins in the large nerves, especially the sciatic; in the skin, which undergoes marked trophic changes and becomes eczematous. At first thin and hardened, the skin becomes adherent to the subcutaneous connective tissue and aponeuroses, involving at the same time the lymphatics and causing a secondary hard edema and hypertrophy of the corium, known as elephantiasis phlebectatica. The associate degenerative changes lead to an interstitial myositis. The bones undergo a rarefying process (osteoporotic osteitis) and in some cases hyperplasia. Most of these changes are especially marked in the

vicinity and margins of the *varicose ulcers*, which usually appear on the inner lower aspect of the leg above the internal malleolus.

Clinical Varieties.—*Hemorrhoids* are the most common examples of phlebectasis and varix (see Vol. IV., p. 141).

Next in frequency are the varices of the spermatic cord (*varicocele*, see Vol. IV., p. 610) and the *varicose veins of the lower extremities.* The patients are usually individuals in middle life who are compelled to labor while standing; multiparous women are especially prone to the latter condition. The pressure of large abdominal tumors and other causes of intra-abdominal pressure also favor the phlebectasis. In the region of the internal and external saphenous the veins appear through the skin as bluish ridges and tortuous discolored elevations, the skin becoming thinned and bluish and reduced in many places to a mere pellicle. The insufficiency of the valves is readily demonstrated by the *Trendelenburg test* as follows: The patient is placed in the lying posture, and the varicose leg is grasped by the foot and lifted to a perpendicular or oblique position. The distended saphenous will at once collapse as the blood is drained toward the trunk. If the finger of the examiner is then applied to the vessel at the saphenous opening, just where it empties into the femoral, so as to compress it firmly and at the same time the patient is instructed to stand up, the vein will continue empty until the finger is removed, when it will quickly fill up by a reflux of blood from above downward, and not, as in normal conditions, from below up. Coughing will also cause a wave of distention or undulation by reflux in the vein, which is not seen in the normal condition. Likewise, a quick tap or stroke on the proximal side of the vein while the patient is standing will be felt like an undulating wave on the trunk of the vein, distinctly appreciable to the finger (Schwartz's test). Fluctuation can also be elicited by applying pressure at two points in the course of a vein, when the deep and superficial veins have become involved. It is easily understood that muscular contractions in the peripheral muscles, instead of favoring the return flow to the heart, force it back and increase the stasis and distention. Delbet demonstrated the influence of valvular insufficiency in increasing the intravenous tension. He introduced a cannula in the central end of a varicose saphenous vein, about the middle of the thigh, after previous cocainization of the skin. The cannula was connected with a mercurial manometer, which at once registered a positive pressure of 16 mm. while the patient was in repose. The mercury rose to 16 cm. after moderate exertion and to 26 cm. when a violent lifting effort was made. Such an enormous increase in the intravenous pressure (which should have been negative with the cannula inserted on the cardiac side in a normal vessel) easily accounts for the great change that occurs in the veins when the stage of valvular incompetency exists.

Queirolo has also determined by careful manometric and kymographic tracings that there is a constant arterial hypertension in the arteries of the legs of varicose

subjects. This arterial hypertension is reduced to normal after the excision of the veins. He made comparative examinations in individuals who had unilateral varices, and found that there was a distinct difference between the abnormal and the normal limbs. He suggests that the local hypertonus may be due to a secondary arteriosclerosis consequent upon the work of the artery in overcoming the enormously increased pressure of the engorged veins when the valves have become incompetent.

When the small cutaneous veins are invaded, they appear as fine, red, injected lines, sometimes in radiating groups, forming rosets under the skin. The upper extremities are rarely involved, usually only as a sequel to tumors in the axillary and subclavian regions; also in arteriovenous aneurisms and in the neighborhood of racemose angeioma. The broad ligaments, the bladder and prostate, and external genitals often become involved (uterovaginal, vesical, and pudendal varices) in later life.

The veins of the abdominal wall become distended about the umbilicus when the portal vein is obstructed, as in cirrhosis, pyelothrombosis, etc., forming the peculiar grouping of the superficial veins called the *caput Medusæ.* The epigastric veins become prominent on the anterior abdomen, and the thoracic veins along the costal arches become ectatic whenever mediastinal or intrathoracic obstructions occur.

Complications.—(1) Rupture of the thin varices, followed by hemorrhage, either subcutaneous or external; (2) phlebitis and lymphangitis; (3) ulcer; (4) neuralgia—are the most frequent and characteristic complications of the varicose state.

(1) **Ruptures** of varicose veins sometimes threaten life and cause death. The bleeding is profuse because there are no valves, and the systolic impulse is increased. Rupture and hemorrhage occur most frequently in hemorrhoids (hence the name). The subcutaneous ruptures cause extensive extravasations, large ecchymoses, and hematomas. When the deep muscular veins rupture, a painful sensation is experienced, known by the French writers as the "*coup de fouet,*" or the "whiplash," not only because of the pain, but on account of the ecchymotic discolorations which follow a few days later.

(2) **Phlebitis.**—The stagnation of blood and the degenerate state of the varicose veins, as well as their exposed position in the extremities, subject them readily to accident. Hence great care must be taken by subjects of varicose veins in protecting themselves against injuries, superficial wounds, and excoriations, no matter how slight, as they readily lead to septic purulent thrombophlebitis.

Lymphangitis is frequently associated with phlebitis as a sequel to injury or infection in the extremities. When this combined infection occurs, the tendency to edema and superficial redness is most marked. There is pain and constitutional disturbance; the neighboring glands participating in the process and often undergoing suppuration.

(3) **Varicose Ulcer.**—This is one of the most constant accompaniments of the varicose state in its advanced stages. It is usually situated on the inner and lower aspect of the leg, along the track of the internal

saphenous. It may begin as a superficial blister, excoriation, or scratch, brought about by itching and eczema. After the loss of epidermal protection, the tissues become an easy prey to infection and the ulceration progresses rapidly and obstinately, on account of the diminished resistance of the tissues caused by the trophoneurotic changes. Syphilitic subjects are particularly prone to this form of ulceration, which assumes the circular, scooped-out character of the syphilitic ulcer. The eczema which accompanies varicose ulcers is usually of the dry and scaly or sweating variety. The sensibility of the skin in the periphery of the ulcer is diminished. The subcutaneous tissue in the chronic neglected cases also participates in the fibroid process, especially when the lymphatics are involved, causing great thickening of the skin, which simulates elephantiasis.

(4) **Neuralgias** are frequent accompaniments of the advanced varicose state, though neuralgia along the sciatic tracts may occur in its worst forms without very marked varicosities of the superficial veins. Sciatic neuralgia of varicose origin is due largely to the development of intraneural varices and perineural scleroses. The pain is felt with greatest intensity in the gluteofemoral region, where the nerve becomes more superficial after its exit from the pelvis. The operation suggested by Quénu for the relief of this type of sciatica consists essentially in the exposure of the nerve and the direct dissection and extirpation of the recognizable intraneural and perineural varices, followed by the combing or raking of the nerve (hersage) with a coarse brush to destroy the smaller varicose veins, and has yielded good results.

Diagnosis.—The clinical recognition of phlebectasis should offer no special difficulties when the superficial vessels are involved, which is the condition met in the vast majority of cases. The diagnosis only offers some difficulty in cases of cavernous hemangeiomata, which may simulate a bunch of varicose veins, especially when seated in the groin. The deep-seated varices cause no special notable manifestation. The large pulsating, purring veins in arteriovenous aneurisms are unmistakable. Varix in the femoral canal may simulate femoral hernia, but the accompanying enlargement of the veins and the disappearance of the swelling by gravity alone quite suffice to differentiate them.

Treatment.—Hygienic and Preventive.—There are many patients whose varicose veins cannot be extirpated or relieved by surgical measures on account of associated constitutional states or diseases which forbid any operation except in conditions of imminent danger to life from rupture, profuse hemorrhage, or septic infection of the varices—*e. g.*, diabetes, nephritis, cardiac lesions without compensation, arteriosclerosis, hemophilia, and the purpuric states, cachectic conditions, extreme obesity, etc. Radical operations are also contraindicated when the deep veins are obliterated by previous thrombophlebitis. In other cases the skin is undermined and involved so extensively that the varices cannot be extirpated without enormous excision of the overlying skin. In these patients, however, the

Trendelenburg ligatures and other palliative operations may be performed with great relief, if not permanent cure. In these and in incipient cases, in which the varicose state causes comparatively little inconvenience, the proper hygienic care of the limbs, with the help of an external support, will enable the patient to live in comparative ease. Change of occupation, habits, etc., such as will diminish the strain on the veins, will aid materially. The skin should be cared for by frequent careful bathing, using hot or cold water, rather than lukewarm, avoiding garters and constricting garments. The main reliance, however, must be placed upon properly fitting elastic stockings, which must always extend from the foot to the knee or higher, according to the extent of the varices, never to be used as sectional leggings about the legs, knee, or thighs lest they aggravate the condition. Trusses and other appliances used to compress the saphenous in the groin, with a view of preventing the reflux of blood in the valveless vein, never accomplish their purpose. No drugs or internal treatment, except those which improve the general health and the arterial circulation, can accomplish any special good.

When rupture and hemorrhage occur in the operable cases, the excision of the bleeding veins under local anesthesia can be readily effected after the hemorrhage has been arrested by an aseptic pad and compressive dressing, supported by an elastic bandage or stocking. In the subcutaneous ruptures and extravasations, rest in bed, immobilization of the limb, and elastic compression with a properly adjusted bandage, extending from the foot to the groin, will prove sufficient. When infective phlebitis occurs, whether of the septic or non-purulent type, the proper course is to ligate the saphenous vein at the saphenous opening, below its entrance into the femoral vein, in order to prevent the possible escape of an embolus from the thrombotic veins into the circulation. In favorable subjects this ligation should be followed by the extirpation of the inflamed veins. When *peri*venous and *endo*venous abscesses form, these should be drained by free incision along the tract including the inflamed vein, thus draining the endovenous abscess or abscesses which so often form in longitudinal or bead-like series. The extirpation of inflamed varicose veins *en masse*, after preliminary ligation of the infected saphenous, has been performed many times, and with excellent results.

Varicose ulcers, in inoperable cases, must be treated by hot, alkaline baths containing dissolved potash soap, or, in eczematous subjects, starch-water. The baths must be prolonged for hours and administered in foot-tubs deep enough to immerse the affected extremity, including the ulcer, while the patient is lying or sitting. The hot-water baths are given alternately with local hot-air baths, applied with any of the numerous appliances now sold by manufacturers for the application of the Tallerman hot-air treatment or Bier's method of hyperemia. The effect of hot air in improving the old callous and deeply infected ulcers is prompt and at times surprising. Venous hyperemia by elastic pressure at the root of the limb, as advocated by Bier for the treatment

of other acute infections, is not beneficial in these cases, but the active hyperemia obtained by the hot-air bath is of immense value in procuring the sterilization of the ulcers and placing them in a proper condition for the radical operation.

The **radical operation for varicose ulcer** consists in extirpating the ulcer in its totality and covering it with Ollier-Thiersch grafts, as is practised in Mayo's method. When the prolonged hot-water baths and hot-air treatment are not available, the best palliative treatment is still hot bathing with water and German green soap, followed by moist antiseptic and astringent dressings. In the inflamed stages the classical and ancient lead-and-opium wash, which still remains by far the most efficient of all the local applications in such cases, should be applied. By keeping the ulcer clean and covering it with lead-and-opium compresses and supporting these with an elastic roller bandage, preferably of porous elastic material instead of the pure rubber (Martin) bandage, which interferes with evaporation, the ulcers will be greatly improved. Still better, a well-fitted elastic stocking may be used. By these means many patients who, for any reason, cannot afford to rest their limbs, can be made tolerably comfortable and vastly improved until the radical operation can be performed. In non-inflamed callous ulcers the old-fashioned adhesive strips sold by the manufacturers in the improved form as zinc oxid (Z. O.) plaster may be used systematically in overlapping strips to cover the entire surface of the ulcer. When combined with baths, aided with an elastic support and changed every twenty-four hours, this method will accomplish wonders in improving the nutrition of the ulcers and often will succeed in healing them, even when the patients are compelled to continue on their feet.

In the neuralgic varicose ulcers Chipault's suggestion may be applied, viz., to stretch the superficial nerves that supply the region, the long saphenous and external saphenous nerve, by an incision in the neighborhood of the ulceration. In connection with the radical cure of the varices by extirpation or ligation this method may be considered as an adjuvant. The graver neuralgias of the sciatic nerve may be treated by Quénu's method, previously described.

The Operative Treatment of Varicose Veins.—With the perfected methods of aseptic technic, the surgical treatment of varix has become one of the most valued acquisitions of contemporary surgery. C. H. Mayo has reported a series of 185 successful operations without a death; and in one clinic (Johns Hopkins) 125 operations have been recorded with 1 case of pulmonary embolism, which recovered. The danger of embolism still exists, but the emboli are non-septic and are of minor significance.

The modern operative treatment of varicose veins is based upon four fundamental procedures: (1) The open *ligature* of the varicose trunks; (2) the *linear section* of the varicose trunks between ligatures, with or without the inclusion of the collateral tracts by *circumferential incisions*; (3) the *open resection of the varicose trunks and secondary*

tributaries; (4) the *subcutaneous resection* of the venous trunks in their totality.

The principles which underlie these operations are: (1) To arrest the hemodynamic reflux of the venous column into the superficial veins (long and short saphenous), when the valves are incompetent and the varicose state is associated with or consequent upon a progressive increase in the intravenous tension; (2) to force the superficial venous circulation from the unsupported subcutaneous veins into the deep muscular trunks when these are not obstructed by previous disease; (3) to remove permanently the diseased venous tracts which have become functionless and dangerous to the organism from the effects of disease or infection; (4) to prevent the direct entrance of blood into the superficial varices (already incompetent from the functionless valves) from the deep intramuscular trunks by the obliteration of the anastomotic branches while extirpating the superficial varices.

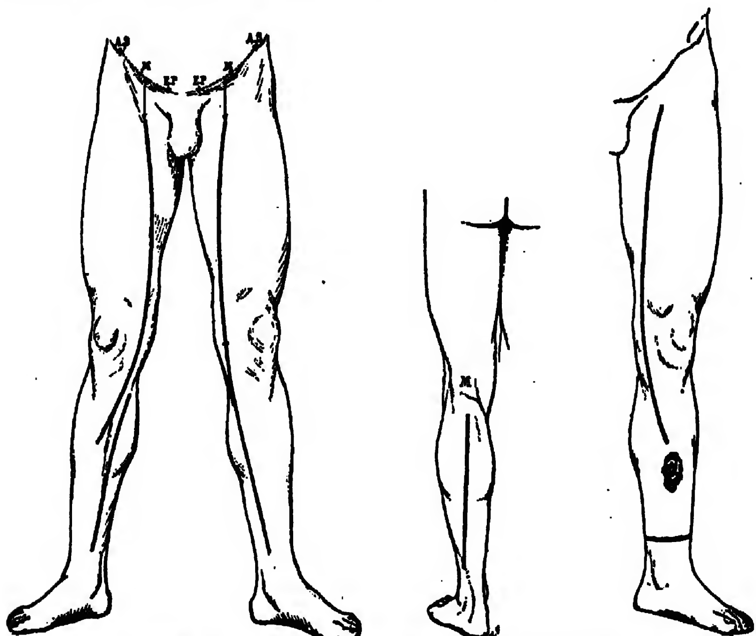
The operations which aim at the obliteration of the venous trunks with the ligature, in order to support the venous column and prevent the venous reflux, may be regarded in a large measure as palliative operations, and those which extirpate these trunks are classed as radical operations, though this designation does not necessarily imply that the varicose state is cured, particularly as in a certain percentage of operations the veins are reproduced and relapse occurs.

The **obliterative ligature** of the saphenous, which was applied by others, was systematized and applied on the basis of its preventing the venous reflux by Trendelenburg, in 1890, who explained the effects of hydrodynamic pressure of the blood column upon the vessel. Trendelenburg's first operation consisted in the division of the long saphenous at the point of junction of the lower with the middle third of the thigh. He subsequently modified this procedure by placing two more ligatures on the saphenous: one above the level of the internal condyle and the other below the knee. Trendelenburg's operation is very simple in its technic and is usually performed with local anesthesia. The long saphenous is approached through a short incision at right angles to its course, and divided between ligatures near the saphenous opening. Each end of the divided vein is doubly ligated with fine chromic catgut or fine aseptic silk.

This procedure has been modified by the excision of small sections of the vein, 4 or 5 cm. in length ("Résections etagées"), by Schwartz, Cassatti, and others.

Schede's Operation and its Modifications.—The *linear division of veins between ligatures* is accomplished by circumferential incisions (circumcision of limbs), and has been associated with the name of *Schede*, who first described it in 1877. A partial or complete circular incision is made in the upper third of the leg, which divides all the superficial veins, including the long and short saphenous, down to the deep tibial aponeurosis. If the circumcision is partial, it should divide at least all the veins in the anterior, internal, and posterior aspects. The same principle is applied by Moreschi in the treatment of varicose ulcers. He

makes two circumferential incisions through the skin to the aponeuroses, the first 4 cm. above the ulcer, the other 1 cm. above the malleoli. The ulcerated area is included between these incisions. The peculiarity of Moreschi's operation is that the skin in the immediate vicinity of the ulcer and between the two parallel incisions is completely undermined and detached by subcutaneous dissection with a knife or scissors, with a view to destroying the varices and their tributaries over a large area within the line of the cross-section. Pizzono also ligates the saphenous at the root of the limb in applying Moreschi's procedure to prevent or diminish the dangers of embolism, which has already proved fatal in



Figs. 60–62.—Complete Extirpation of the Saphenous Tracts (After Terrier and Alglave.)

Fig. 60.—Incision for complete extirpation of long saphenous.

Fig. 61.—Incision for short saphenous.

Fig. 62.—Incision for extirpation of long saphenous with Schede-Moreschi circular section below ulcer.

one case after this operation. Rindfleisch (1907) makes multiple spiral incisions around the limb and packs the wound to obtain deep scars.

Resection.—This may be partial or complete. The partial consists in the removal of one or more sections of the varicose trunk by a series of interrupted incisions, as suggested by Madelung in 1884, and systematized by Schwartz, in France, since 1888; in the complete, the whole of the main trunk of both saphenæ is removed (Madelung). This has been recently systematized by Terrier and Alglave, who have practised and advocate the most extensive resections by continuous *open incisions* thus far described. They call special attention to the influence of direct

anastomotic branches which reach the surface veins through perforations in the deeper aponeuroses and which supply the superficial varices with the greatest amount of blood. They advocate extensive extirpations of the main trunks and of their tributaries in order to intercept these deep branches, which are found most numerously near the mouth of the saphenous and Scarpa's triangle and the middle of the thigh. They report 21 cases successfully treated by extirpation of both the internal and external saphenous, throughout their whole length, with or without inclusion of the overlying skin, according to whether this is involved in the varicose process or not (Schwartz's method). The combined total resection of the saphenous trunks is occasionally assisted by circumcision on the Moreschi plan when the case is complicated with varicose ulcer. Madelung's operation has also been modified by Ledderhose, who, in addition to the extirpation of the veins, makes a series of *longitudinal incisions* along the inner aspect of the leg from the knee to the malleolus, by which he expects to intercept and obliterate all the tributaries lying between the knee and the ankle.

Open Section and Thrombectomy.—Kraemer recommends the systematic incision and evacuation of all thrombotic varices forming large irregular cavernous plexuses. He opens the venous cavities and tortuous veins longitudinally, and carefully wipes out the clot and allows the wound to come together by simple approximation and bandaging. He has operated fifty times by this procedure with great relief to the patients and rapid obliteration of the varicose area.

The saphenous veins may be resected in their totality by continuous open incisions or by a series of short, interrupted, "buttonhole" incisions made along the length of the saphenous tracts, from the groin to the ankle and from the knee to the ankle. These are the so-called subcutaneous resections, and the methods by which this is done vary with different operators. Cassatti describes a method of tearing out the vein after mobilizing the main trunk by subcutaneous traction and dissection. Narath extirpates the entire saphenous through a series of small interrupted incisions, which permit the vein to be isolated and detached from its surroundings by traction and subcutaneous manipulations. The incisions are made at intervals of 10, 15, and 20 cm., the vein being isolated and brought out by hemostats through each one of the openings successively without dividing it, until the vein has been completely loosened from its tributaries throughout its length, when it is extracted whole from the groin to the ankle after ligation near the femoral incision. The incisions are not over 1 cm. in length and are closed with a single suture. He is very well satisfied with this procedure, which he has practised successfully for many years.

Narath's method has been much simplified in suitable cases by the use of an ingenious device of C. H. Mayo, of Rochester, Minn., which he describes as the enucleator (Fig. 63). It consists of a $\frac{1}{4}$-inch ring of steel with a long handle, the whole instrument being not unlike a blunt uterine curette, bent at an angle near its tip. He also uses for

the same purpose a pair of long forceps which form a ring at the tip when closed.

The present technic is as follows: The vein is sought for and severed in the upper third of the thigh. The proximal end is ligated; the lower end is passed through the ring formed by tips of the blades of the special long probe-like instrument which he has devised, or through his ring-tipped forceps, and clamps are placed on the end of the vein. By a gentle pushing force, the vein being held to make tension and the tissues steadied on either side by an assistant, the ring enucleator or forceps is pushed down the vessel for 6 or 8 inches, tearing off the lateral branches, when the point of the instrument is forced against the skin from beneath, and a small incision is made to the

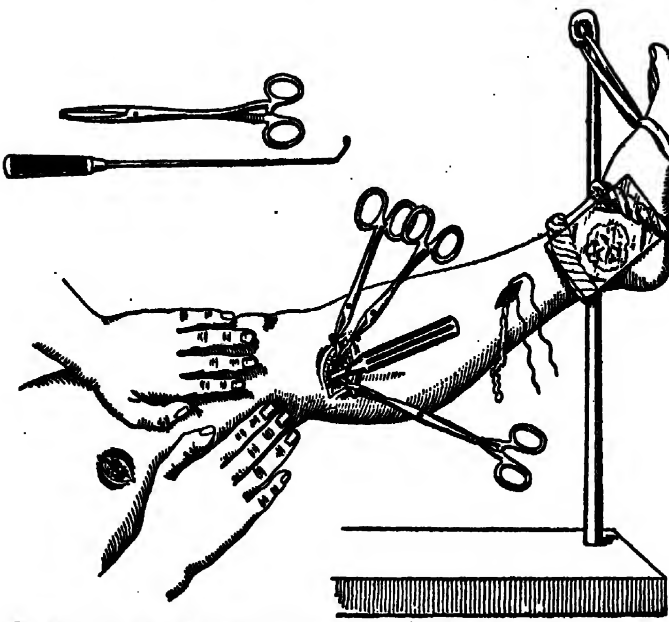


FIG. 63.—C. H. MAYO'S SUBCUTANEOUS METHOD OF EXTIRPATING VARICOSE VEINS.

ring or the forceps, which is pushed through the opening, holding the vein like a thread in a needle's eye. The vein loop is drawn out of the opening and also from the instrument, which is removed, rethreaded in the vein, and is pushed down to a lower point, where a small incision is again made and the process of removal repeated. The small lateral branches are torn off, and, as a rule, have enough contractility left to retract and close themselves. Should the main venous trunk break, a new incision is made below the knee, the vein exposed and divided.

If it is found that calcareous deposits, sacculation, or extreme weakness of the walls render the case unsuited to the subcutaneous method, and this occurs in about 10 per cent. of the cases, the open resection should be made, undermining only the section about the knee. Hemorrhage is avoided by position. An ordinary gynecologic standard

is placed in position and the leg is raised in the straight or extended position and supported by the ankle. The position renders the limb practically bloodless and also secures elevation and accessibility to the field of the operation. Should any branches cause more than ordinary hemorrhage, it can be checked by a pressure pad held against the skin over the region from which the veins are removed, or by gauze packs which are left for a few minutes in the incision from which it arises. The varicose ulcers are excised and graftod witth Ollier-Thiersch grafts. After this has been done, Mayo applies a twisted roll of gauze about the leg above and below the grafted area, to support a sheet of sterile celluloid or a wire gauze held in place by a strip of adhesive plaster. The final bandage is applied from the foot to the body and a small area is cut out over the protective. This serves as a window through which the condition of the graft can be watched healing usually taking place under one dressing.

In Mayo's experience (185 cases) the subcutaneous removal of that portion of the internal saphenous vein extending from 8 to 4 inches above the knee accomplishes by one method all that is possible to obtain by either the Trendelenburg or Schede operation, in interrupting the main channels of superficial circulation and also checking communication with the deep circulation of this region. Should there be a persistent eczema in spite of previous preparation, the operation is proceeded with as usual, the ulcer being excised before enucleation of the vein. The ulcerated area is skin-grafted. The eczematous area is now painted with compound tincture of benzoin or an acetone solution of gutta-percha, after Murphy's plan, which acts as an aseptic varnish, thus literally sealing this surface against infection until the incisions have healed. The dressing is applied and the leg maintained in a somewhat elevated position for twelve days. The patient is then allowed to get up, wearing an elastic porous supporting bandage for a few months.[1]

W. Wayne Babcock has improved upon Kellar's suggestion by extracting the vein after it has been supported and straightened by passing through it an acorn- or olive-pointed stylet. This is introduced into the vein at its terminus near the femoral and pushed down through the vein as far as it will go down the limb. The upper bulbar end of the stylet is made fast to the vein by ligation. It is then pulled upon vigorously by bringing out through the lower incision. The traction pulls the vein loose from its surroundings, tears off the venous branches, and causes the vein to be extracted as a pleated mass attached to the upper end of the extractor.

It is evident that all these methods of subcutaneous isolation and extraction of veins, of which Mayo's still remains the simplest and most practical, must fail in all chronic cases in which the main trunk of the vein remains very tortuous, convoluted, forming a congeries of adherent and friable veins, intimately blended with the skin.

[1] Kellar (quoted by Babcock) attempts to facilitate the extraction of the saphenous vein by passing a stout thread through the vein by means of a probe or twisted wire, tying it firmly to one of the divided ends of the vein after slitting the sides of the vein for a short distance, then making traction upon the other end of the thread, causing the vein to be turned inside out, in which condition it is finally pulled out through either the upper or lower incision previously made to reach the vein at its terminus near the groin, and the other in the leg or lower thigh.

Results.—Perthes reports 9 relapses in 41 cases operated in Trendelenburg's clinic. In a series of 41 cases operated in Halsted's clinic by Trendelenburg's method, Miller reports that 79 per cent. have been cured or greatly improved. Goerlich, in an exhaustive review of the literature, in which 1425 cases reported by 42 operators are analyzed, finds the cures from 65 to 85 per cent. after ligature of the internal saphenous. The Schede operation in the Johns Hopkins clinic (19 cases) yielded 33 per cent. cures. This operation and other modifications based upon the same principle are open to two serious objections: (1) That paresthesias and disturbances of sensibility follow the unavoidable division of the superficial nerves; (2) that edema persists in the distal parts from lymphatic as well as venous obstruction. The results obtained by this method do not justify its preference to either the direct Madelung or subcutaneous method. In many cases, on account of its simplicity, the Trendelenburg operation will still remain the method of election.

In deciding whether an operation should be performed or not, especially in cases in which the history of previous phlebitis is given, this test advised by Mayo should be applied: "An elastic bandage is applied from the foot to above the knee. If this bandage can be worn with comfort, an operation should give relief. If the bandage causes discomfort, it is probable that the superficial vessels are necessary to the circulation of the limb." When the varices form large masses, in which the skin covering is thinned to a mere pellicle, it is advisable to combine the excision of the veins with an overlying strip of skin.

Embolism.—In spite of the control of postoperative phlebitis by asepsis, there still remains an apparently unavoidable risk of embolism, even in the most aseptic cases. Sterile emboli (so-called "bland" emboli) are discharged from the proximal side of the ligature in the saphenous, or from the stumps of the extirpated radicles, and are sped along the deep anastomotic trunks to the general circulation, where they give rise to pulmonary embolism. Miller reports 1 case of embolism, the patient recovering after a serious alarm. Goerlich, in 147 Trendelenburg operations, reports 2 cases of embolism. He has collected in all 8 cases following operations for varicose veins. Embolism occurred after the simplest as well as after the complicated procedures.

There seem to be three fairly distinct types of postoperative pulmonary embolism: The mildest is transient and comparatively harmless, causing more or less marked respiratory distress for a few hours. The more severe result in definite infarct, which may cause symptoms for four or six weeks and probably leave a permanent pulmonary lesion, while the most severe cause immediate death by occlusion of the pulmonary artery. The symptoms are: Sudden dyspnea, cyanosis, tachycardia, and signs of collapse, accompanied by rise in temperature. The symptoms may subside rapidly, may persist with physical signs of pulmonary infarct or death. The treatment essentially consists in the administration of oxygen freely and continuously as long as dyspnea lasts, and to ease the respiration with hypodermics of morphin, atropin, strychnin, digitalis, and nitroglycerin. Trendelenburg's recently suggested method of extracting the clot directly from the pulmonary artery may be also considered (p. 172).

Relapse is more likely to follow the single linear division of the veins than after the more thorough extirpations. Nevertheless, relapse will occur even after extensive resection (Alglave, Terrier). The causes of relapse are: Secondary dilatation of small superficial tributaries of the extirpated or ligated vein, which enlarge and connect with the deep muscular veins through direct anastomotic branches; (2) the reëstablishment of direct end-to-end communication through the scar, especially after ligation; (3) the regeneration of the veins believed at one time to be impossible, but since proved to be of frequent occurrence.

TRAUMATISMS AND WOUNDS OF VEINS.

The behavior of the veins after injury, their mode of repair and regeneration, and the natural process of hemostasis are all in accordance with the identity of their origin and structure with the arteries. The veins, however, on account of their much greater total area and superficial distribution, are more frequently exposed to injury, and especially to surface injuries, against which they react more than the arteries. The thinness of the venous coats exposes the delicate intima to irritative and destructive changes which are manifested by the prompt formation of obliterative thrombi, giving to venous injuries their most striking differential, clinical, and pathologic characteristics.

Wounds of veins are either *subcutaneous* or *open*. The subcutaneous include contusions, bruises, ruptures, lacerations, tears, stretching or twisting, and the grinding or attrition injuries. The open wounds are subdivided into penetrating and non-penetrating; complete and incomplete; direct and indirect; immediate and mediate; and, according to causation, into punctured, incised, contused and lacerated, and gunshot wounds.

Symptomatology.—The hemorrhage which follows after the wounding of a vein may be either external, interstitial, or internal. When the external wound is large and the wounded vein is near the surface, the blood is seen to escape from the vessel; it is of a dark red, almost black color, and flows in a continuous stream or gushes out in a vigorous jet. The force with which the stream is ejected is less than in the arteries of the same relative size, unless an obstacle interferes with the venous return on the proximal side of the wound, or when pulmonary cardiac disturbances exist which interfere with the emptying of the right heart. The venous stream may be projected at a distance of a yard or more from the wound under these conditions, as in punctured wounds of the anterior jugular in the course of a tracheotomy for diphtheritic asphyxia. This continuous flow, as distinguished from the intermittent jet of the arteries, is the most distinctive feature of venous hemorrhage. The continuity of the stream may be interrupted or, rather, reinforced at irregular intervals which are not synchronous with the heart-beat by the effect of the respiratory movements or by peripheral muscular contractions, which momentarily interrupt the circulation in the central or peripheral vein. Expiration increases the hemorrhage in

the lower extremities, the intravenous tension in the great intrathoracic trunks being increased; muscular contractions compress the peripheral veins and drive the blood out of the wound with sudden violence, as is seen in venesection.

If the injured vein is of small caliber, the hemorrhage is quickly arrested spontaneously by the formation of a provisional clot. If the vein is of large size and the wound a wide one, the hemorrhage may cause death by fatal syncope. Thus a wound of the internal jugular may cause death almost as quickly as a similar wound of the common carotid. This promptly fatal termination is especially likely to occur in injuries of the jugular, subclavian, axillary, and femoral veins.

Internal Venous Hemorrhage.—When veins are ruptured subcutaneously or wounded in the deeper tissues (stabs, sword thrusts, gunshot wounds), the blood is extravasated in the perivascular connective tissue. The amount of blood extravasated depends upon the caliber of the vein and the size and character of the wound. If the wounded vein lies in a serous cavity, as in the pleura or peritoneum, or in the loose areolar spaces of the mediastina, the hemorrhage will flow unchecked in quantities and death will follow in a few minutes or hours. Wounds of comparatively small veins in the splanchnic cavities (pleura and peritoneum) may give rise in this way to most alarming and even fatal hemorrhages.

Subcutaneous hemorrhages in closed or partially closed wounds will lead to extensive extravasations and hemorrhages, but less than in the arteries. The hemorrhage from a comparatively small vein in regions where there is an abundance of loose connective tissue may diffuse itself over a very wide area as a thin but wide-spread discoloration of a dark bluish hue. This is particularly true of wounds of the scrotum, penis, groin, and thigh, neck, face, and axilla. After circumcisions, varicocele, or hernia operations these wide-spread black-and-blue discolorations are not infrequently observed as the result of imperfect venous hemostasis. Fortunately, these superficial extravasations, in spite of their large area of diffusion, usually disappear without interrupting the patient's recovery. The real hematomas, or localized blood collections, remain much longer in the tissues and sometimes seriously interfere with the healing of the wounds, compelling a reopening of the wound to give issue to the pent-up blood.

Spontaneous Hemostasis.—The arrest of hemorrhage from a wounded vein is more readily effected by the natural process of hemostasis than in the arteries, and on this account venous hemorrhage is less dreaded and less difficult to control than arterial bleeding. Partial or incomplete wounds of veins bleed more copiously than the complete wounds and transverse sections. When a vein is completely divided, it retracts within its sheath, and its open mouth contracts so that the lumen is narrowed, but never to the extent that is observed in the arteries. The lack of elasticity and rigidity of the venous walls allows them to collapse and come together, unlike the arteries, which gape open. The lesser elasticity and contractility of the veins is also shown

in the lacerated and contused wound by the inability of the inner and middle coats to curl up and retract, the intima and media only retreating 2 or 3 mm. within the adventitia without curling and rolling.

To compensate for this lack of retractility and contractility the valvular mechanism of the veins (barring the great central venous trunks, where this mechanism does not exist) prevents the flooding of the wound when the reflux of the blood-stream on the proximal or cardiac side occurs, while on the distal side the low tension of the peripheral venous circulation allows the thin and collapsed veins to be readily compressed and obliterated by the clotted blood and the surrounding tissues. The importance of the valves in diminishing the hemorrhage of wounded veins is strikingly shown in the rupture of the varicose veins of the lower extremities, in which the bleeding is profuse and persistent, in consequence of the incompetence of the valves and the rigidity of the veins themselves. The dangers from hemorrhage is also shown in the sinuses of the dura mater, which, in consequence of their rigid walls, absence of valves, and lack of retraction, remain open when wounded, bleeding profusely and fatally, unless prompt hemostasis is obtained. On the other hand, the ease with which a wounded peripheral vein can be controlled in normal conditions is illustrated by the prompt hemostasis which follows the mere application of a bandage and superficial compress after venesection.

Conditions which Increase or Diminish Venous Hemorrhage.—Whatever influences the intravenous pressure will also influence bleeding in a venous wound. If a constricting bandage is lightly applied on the cardiac side of the wound in a vein of the extremities, the hemorrhage will at once be aggravated by the general congestion of the veins below the constriction. This statement is well illustrated in venesection, in which the bleeding is continued as long as the constricting band is kept up with just sufficient pressure to interfere with the return flow of blood; its mere removal at once stopping the hemorrhage.

In *heart disease* due to valvular insufficiency and associated with chronic asystole, the venous tension will be increased and likewise the hemorrhage. Apart from these mechanical causes, in the dyscrasic states (hemophilia, scurvy, purpura, biliary infections, etc.), natural hemostasis is prevented by *diminished coagulability of the blood.*

Asepsis is a powerful factor in diminishing thrombus formation: In aseptic wounds and traumatisms the permanent closure of a venous wound is rapidly effected with a minimum of thrombus formation. In fact, after an aseptic ligature, there should be only a small clot, and the fact that the thrombus is not necessary to the process of repair is strikingly illustrated in the healing of sutured veins which cicatrize perfectly without thrombus formation, leaving the lumen pervious and the circulation uninterrupted. When, however, infection occurs, the pyogenic micro-organisms penetrate into the vessel, attack the endothelium of the intima, and, spreading by continuity, cause degenerative and destructive lesions in the endothelium, which at once precipitate

coagulation and thrombus formation. Suppuration then follows, with purulent thrombophlebitis and all its dangers as a sequel.

Complications of Venous Wounds.—It was the liability to metastatic abscesses and the pyogenic bacteremia which followed in the wake of septic thrombosis and embolism which gave to venous wounds their bad reputation and made the veins the *noli me tangere* of the older surgeons. At present the mechanical effects of migrating emboli, which are comparatively insignificant in frequency and gravity, alone remain as possible sequels of venous thrombosis after surgical operations on veins. Another complication which the modern technic of wounds has largely eliminated is *the aspiration of air into the larger veins*, especially in the neck, causing *air-embolism*. (Vol. I., p. 452.) Fat embolism is a more frequent complication. (Vol. I., p. 462.) For *gunshot wounds* of veins see Vol. IV., p. 979.

Foreign bodies, fine shot, bullets, splinters, fish-bones, needles, and other foreign bodies may find their way into the larger veins as a very rare occurrence. Pluquet, J. Liddell, Stromeyer, Lambron, S. D. Gross, Audrett (quoted by Bouglé) report curious cases of this kind. These foreign bodies usually cause no serious disturbances as long as they are aseptic; they become isolated and encysted, with or without obliteration of the vein, and remain indefinitely fixed in the venous wall or its immediate vicinity. When the foreign body is septic, it will be followed by thrombophlebitis with all its consequences.

In wounds of the smaller veins very little is required to arrest bleeding. The walls collapse by mere atmospheric pressure, and the pressure of the clamp or mere gauze packs will usually suffice to obliterate them. Hot irrigation with physiologic salt solution or, in suppurating wounds, irrigation with a weak hydrogen dioxid solution, if it is followed by a systematic packing of the oozing area, will usually suffice to arrest the hemorrhage. In deep wounds, in which a bleeding vein cannot be seen plainly enough, it is best to catch it in a forceps, leaving this in place for twenty-four hours (vena cava, Helferich). In the wounds of the endocranial sinuses, in which the rigidity of the venous walls interferes with the normal collapse of the veins, systematic packing with sterile gauze or suturing will be usually sufficient to stop the bleeding if the pack is sutured in place. In veins in the bone-marrow or in the diploë, gauze pressure kept up for some time will suffice to arrest the bleeding. It may be convenient in some cases to plug with absorbable catgut wool or to smear with Horsley's wax (oil of sweet almonds, 6 parts; wax, 1 part; salicylic acid, 1 part).

The Ligature and the Suture.—The Ligature.—The surgeon's preferred hemostatic agent in venous as well as in arterial hemorrhage is the ligature. It is by far the most simple and certain of the hemostatic agents, and should be applied to all veins of small caliber or even those in which the obliteration of the lumen is of little consequence to the distal circulation. In regard to the functional results, it may be safely asserted that the obliteration of the veins, even of the largest trunks, by the ligature, is a matter of far less consequence than the obliteration

of the corresponding arteries. The ligation of a vein may be *lateral* or *total.* The partial (lateral) ligature does not obliterate the lumen; the complete (circular) does. Since the suture has been so successfully introduced in venous surgery, the lateral ligature has become much restricted in its application, and is now practically limited to the ligation of tributary branches, which have been cut or injured too near the main trunk to permit of their separate ligation. Wounds involving only a part of the circumference of the vein (referring to the main vein) are closed by lateral phleborrhaphy. The total obliterative ligation of veins is applied to both ends. Bleeding rarely occurs from the proximal end. It is the peripheral end that bleeds, but the possibility of infection through the open mouth of the vein on the proximal side calls for its closure, if only as a protection against sepsis and thrombosis.

The collateral circulation after the ligation of the large venous trunks. After asepsis had robbed the ligation of veins of its terrors, the fear of gangrene from the obliteration of the large venous trunks continued to instil fear in the minds of surgeons until comparatively recent times. It was supposed that the collateral circulation, which is apparently much less provided for in the venous circuit than on the arterial side, was insufficient to prevent the stagnation of the circulation in the limbs after the ligation of the main trunks, especially the femoral. The fear in preantiseptic times was well founded, because the ligature was always septic and led to extensive thrombosis of the vein, including many important collaterals. The lymphatics were also involved in the septic process, and these two factors, diffuse septic phlebitis and lymphangitis, very seriously interfered with the establishment of the collateral circulation. It is only in recent years that the safety of the ligature has been recognized. The complete misconception of the factors which promote the collateral circulation after venous ligation at the root of limbs by the simultaneous ligation of the associate artery was also realized. It is now understood that the reverse doctrine holds good, and that *the most powerful agent in bringing about the establishment of the collateral circuit after venous ligation is the preservation of the arterial circulation in its most perfect functional integrity,* in order that the full benefit of the arterial pressure may be felt, through the capillaries, in the peripheral veins. The joint injury of both vessels is the most certain way of causing gangrene of the limb. In fact, Bodaert showed experimentally that if the femoral vein is ligated at the groin, aseptically, and with care not to injure the lymphatics, very little or no edema, much less gangrene, follows the ligation. When edema occurs after the obliteration of the femoral, it is due to the involvement of the accompanying lymphatics or to the production of a long thrombus which obliterates the veins over *a large area.*

Since the importance of rigorous asepsis has been better appreciated, the *femoral vein* has been ligated a great many times without gangrene.

Niebergall reported 35 cases of femoral ligature, 25 for extirpation of a tumor, 10 for wounds, and in all there was only 1 case of sphacelus of the foot, whereas when the artery and vein were simultaneously ligated, gangrene occurred in 14 out of 24 cases. In 24 cases of single ligation of the femoral vein, Kammerer records 2 gangrenes; in 22 simultaneous injuries of artery and vein there were 12 gangrenes. Fränkel reports 53 cases of the isolated ligation of the common femoral with 1 gangrene. Cyanosis frequently develops after the ligation, but no gangrene unless the artery is involved.

The same effects have been observed in the simultaneous ligation of both popliteal vessels. A. Schorong reports, in a study of 45 simultaneous arteriovenous injuries resulting from direct crushes of both artery and vein, that there were 75 per cent. gangrenes, and when the popliteal vessels were involved, gangrene followed in 100 per cent. Apart from these severe injuries, the combined obliteration of the artery and vein of the lower extremity is always fraught with great peril to the limb, though in chronic conditions of arterial obstructions (tumors, aneurisms) the artery and vein may be injured without gangrene, as has been shown in a considerable number of extirpations of aneurisms in which both vessels have been sacrificed. In recent aneurisms, however, the coincident injury of the veins, with the obliteration of the artery, is a perilous accident.

The comparative benignity of the ligation of the large venous trunks in other parts of the body has been amply demonstrated by the successful and abundant experience of the last decade. Not only have the *internal jugulars* been ligated separately, but they have been both ligated at variable intervals, as well as extirpated simultaneously in the same subject, while performing extensive extirpations of malignant growths in the neck. Ligation or extirpation of the jugulars has since become a regular procedure whenever their removal is indicated either for injury or disease.

The *subclavian* and *axillary* have been repeatedly ligated and resected. The ligation of one or both innominate veins is well tolerated in dogs (Leotta).

The *superior vena cava* has never been ligated in man, but Julius Fischer, in a very careful study of the reported pathologic obstructions of this vessel (104 cases, of which 42 were complete), found that while stasis existed in the tributary area in many cases, in the majority a fairly effective collateral circulation was established. Mariotti (1906) has experimentally tried the ligation of the cava on dogs, with unsatisfactory results. According to Leotta (1907–8), 75 per cent. of ligations of the superior vena cava succeed in dogs when the ligature is applied above the asygos.

The *inferior cava* has been the subject of numerous experimental studies (Clermont, Leotta) to test the efficiency of the collateral circulation after its ligation. The conclusion arrived at is that the *ligation* of the vena cava *above* the origin of the renal vein is extremely dangerous on account of the interference with the kidneys, but that it is comparatively safe *below* the line of the renal vessels; especially if the collateral circulation has been given time to develop by long compression or partial obliteration of this great trunk. The *vena porta* has been ligated for injury during operation for removal of hydatid cyst by Brewer, New York.

The Suture of Veins.—The ligation of the great venous trunks, however, has been supplanted by the suture (phleborrhaphy) whenever the conditions permit of its application without obliteration of the vessel.

The suture of veins was first suggested by Gensoul (1833), who experimented with it unsatisfactorily on the jugular of a horse, septic infection following. Czerny (1881) is credited with the first case of venous suture under aseptic auspices; yet the wound was badly infected from an esophagotomy performed for a foreign body, the patient subsequently dying from pyemia and secondary hemorrhage. But Schede's paper, in which he reported the first successful suture of the vena cava inferior and coincidentally related his large and satisfactory experience in the suture of veins, turned the tide in favor of the suture, which has since supplanted the ligature in the surgery of all the large venous trunks whenever it is possible to close the wound without obliterating the vessel.

Bottini (1892) was the first surgeon to ligate the inferior cava successfully. His patient survived three years. Since Bottini's case this great vein has been resected three times—by Zoege v. Manteufel, Ullman, and by Lexer. In this last case a section of the vein was deliberately excised between two ligatures in order to remove a malignant growth of the kidney; in the other two cases a large gap in the vein was sutured, thus restoring the continuity of the vessel. In addition to these three resections the vein has been ligated eight times, including Bottini's case; lateral ligatures have been applied to it five times, and it has been *sutured eleven* times; it has been clamped with forceps to arrest hemorrhage, leaving the clamps *in situ* twice, and *tamponed* once for a small wound. In all, 28 operations for hemorrhage have been performed upon this vessel from 1892 to January, 1908.

Lateral and Circular Phleborrhaphy.—The suture may be applied to the veins in continuity (lateral phleborrhaphy) in longitudinal, oblique, and transverse wounds. The rules which govern the technic of arterial suture apply here with the same force and with greater advantage. The thinness, softness, and suppleness of the venous walls make them more amenable to the suture than the arteries. The low tension of the venous current also favors the maintenance of accurate apposition without tension, and favors the work of repair. The suture of veins is, therefore, not only a much easier procedure than the suture of arteries, but the healing of the line of suture takes place with regularity, provided sepsis has been rigorously excluded.

In applying the suture to veins, the principle of confronting intima to intima and Carrel's technic, by which the edges of the veins are lifted up with terminal traction threads and transformed into straight lines, is the simplest and safest method. The circular or end-to-end suture of veins requires more care in the proper adjustment of the edges, but is performed in the same manner as directed for the arteries. It is indicated whenever the wound in the vein involves over two-thirds of its circumference or when it has been completely divided or resected.

In spite of their lesser elasticity, the veins can be stretched fully 50 per cent. without permanent damage—*i. e.*, when the vein is free

from its adhesions to the sheath (Murphy, 1897). Payr, of Gratz, was able successfully to resect 4.5 cm. of the femoral vein involved in a carcinomatous growth by his method of invagination with magnesium rings. He kept the limb flexed at the thigh to prevent overtension. The fact that the veins do not fracture as the arteries do, and that there is no curling in of the intima and media after transverse sections, in addition to the other conditions previously referred to, favors the application of the circular method of suture much more than in the arteries. The technic does not differ in any way from that of circular arteriorrhaphy, and the method of Carrel is to be preferred. Since Schede popularized the suture of veins, apart from the pulmonary veins, the superior vena cava, and the azygos (resected once by Faure in posterior thoracotomy), all the large veins have been successfully sutured.

Probably the most daring operation in surgery is that recently proposed and done by Trendelenburg (Leipzig) for the removal of emboli blocking the pulmonary artery. While experimentally feasible, and successful in the calf and dog, the three attempts to save patients dying from embolic pulmonary obstruction by Trendelenburg's method have failed. The entrance into the pulmonary artery is effected by an incision in the right ventricle, the emboli are aspirated by a special pump, while hemostasis is obtained by compressing the superior cavæ.

Circular phleborrhaphy has been performed much less often than the lateral. Kümmel (Hamburg) reported the first case in 1890, followed by Krausse (1895) and Payr (1900)—*all femoral*, and technically successful. The *vena portæ* was resected for a malignant growth, and reunited by circular suture by Depage, of Brussels. Vidal (de Perigueux) reported the first and only recorded case of *terminolateral transplantation of the vena portæ into the cava* for the relief of hepatic cirrhosis. The patient succumbed in twenty-four hours.

The *subclavian vein* has been united by circular suture once recently (1907) by Goyanes, of Madrid.

The reparative process in veins after suture does not differ materially from that of the arteries. The dangers of thrombosis and embolism are not necessarily greater after venous suture than after the ligature unless septic infection occurs. Hence the extreme care that must be taken with the technic. For the same reason the suture is contraindicated in all inflamed veins and infected wounds.

Phleboplasty.—"Patching of veins" by borrowing and transplanting parts or whole sections of veins from other regions of the body—like grafts—has been experimentally and successfully done on animals by Taddei, Carrel, Mariotti, and others. Adjoining veins, in cases of injury, have been utilized to cover defects in the vein, and whole circular sections have been interposed between the ends of divided arteries by Carrel and others, experimentally, and by Goyanes and Lexer after the extirpation of aneurisms. (See "Aneurisms" and "Surgery of Arteries," p. 138.)

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HEMORRHAGE.

Definitions.—By hemorrhage is meant an escape (extravasation) of blood from the blood-vessels or the heart. The blood may escape out of the blood-vessels, either as the result of a direct break or solution of the continuity of the vessel-wall, or by cellular (so-called molecular) changes in the tunics of the vessel, or by alterations in the composition of the blood itself which favor its pathologic transudation through apparently normal vessels. Hemorrhage may be *external* if the blood escapes outside of the tissues; *internal,* if within the body. According to the vessels involved, it may be *arterial, venous, capillary,* or *parenchymatous.* According to its extent, it may form minute punctiform *extravasations* (petechiæ); larger patches, *ecchymosis; hematomas,* when the hemorrhage is sufficient to form appreciable swellings and tumors containing circumscribed collections of blood. *Hemorrhagic infarcts* are circumscribed areas of extravasation, caused by progressive overflow of blood in a region in which the main terminal vessel is blocked by an embolus or thrombus, and the collateral vessels are unable to adjust themselves to the new conditions of increased tension and intravascular pressure—usually in the terminal arteries of the lungs, kidneys, spleen, brain, or other internal organs. (See Thrombosis and Embolism.)

Hemorrhages are also specifically designated by the names of the organs in which the hemorrhage occurs, as *epistaxis,* nosebleed; *hematemesis,* or *gastrorrhagia,* gastric hemorrhage; *hemoptysis,* coughing of blood; *metrorrhagia,* uterine hemorrhage; *hematuria,* bloody urine; *hemothorax; hemopericardium; hematorrhachis,* hemorrhage into the spinal canal, etc.

Pathogeny of Hemorrhage.—The *pathogeny* or essential causation of hemorrhage may be summed up into: (*a*) *Traumatic* hemorrhages or those caused by injury or mechanical violence, and are those which directly concern the surgeon; (*b*) *pathologic* lesions and degenerative changes in the vessel-walls (organic or angeiopathic hemorrhage), which should include as a subdivision the alterations of the walls caused by disturbances in the innervation of the vessels (neuropathic and neurotrophic hemorrhages); (*c*) *dyscrasic* or *hemopathic* hemorrhages, caused by changes in the blood itself, which increase its fluidity and favor its extravasation.

The mechanical causes of hemorrhage (fully considered in the sections on the Surgery of the Arteries and the Veins) may be briefly stated as *wounds* and *injuries* of the blood-vessels from *without,* by puncturing, penetrating, incising, contusing, and crushing instruments, weapons, etc. The *erosion* of vessels by ulcerative processes of septic origin, ulcerating growths; by *perforation,* by animal parasites (uncinariasis, strongylus disease, distoma, echinococci), and by erosion, caused by diverse inflammatory and degenerative lesions involving the blood-vessels (gastric hemorrhage in peptic ulcer, metrorrhagia in degenerative disease of the endometrium, hemoptysis in pulmonary tuberculosis). Among

the mechanical causes must be included the rupture of the blood-vessels, whether arteries or veins, when diseased, by sudden exaggeration of the blood-pressure, as in apoplexy, hemorrhoidal flux, and other intestinal hemorrhages caused by obstruction of the portal circulation, etc.

The *neurotrophic dyscrasic* hemorrhages may be classified under the various conditions which underlie their causation. These conditions, however, are far from being well understood. The hemic intoxications or toxemias which injure and alter the delicate and sensitive tunics of the blood-vessels also produce changes in the physical and chemical composition of the blood, affecting its coagulability and thus favoring its escape through the vessel-walls.

The histologic lesions observed in the vascular walls in the hemorrhagic diseases and conditions caused by the presence of micro-organisms and their toxins in the blood are variable, but they may be summed up as a cloudy swelling, edematous swelling of the endothelium of the smaller capillaries—sometimes to the extent of obliterating the lumen of these vessels; fatty, hyaline degeneration and, frequently, a parenchymatous degeneration of the muscularis of the arterioles—this lesion, however, being secondary in importance to the endothelial changes which are essential and fundamental in the process.

In the great septicemias in which not only the toxins but the living organisms themselves infest the blood in large numbers (*e. g.*, typhus exanthematicus, bubonic pest, and in some of the general staphylococcus and streptococcus infections)—the numerous punctiform and larger extravasations which occur on the skin and mucous surfaces are accounted for by the presence of living organisms which plug the capillaries in large numbers. They attract masses of leukocytes which accumulate in the smaller veins and capillaries, forming gelatinous plugs or thrombi. The walls of the capillaries, thus obliterated, undergo nutritional and degenerative changes which make them permeable to the blood elements, thus accounting for the minute but visible hemorrhages.

The neuropathic hemorrhages are the least understood. They are evidently dependent upon disorders of the sympathetic or vasomotor nerves. Menstruation is a physiologic type of these hemorrhages, and certain epistaxes, hemoptyses, gastrorrhagias, the hemorrhoidal bleedings of a periodic type, occurring as vicarious hemorrhages when the menses are suppressed, are conspicuous in this group.

General Physiologic and Histologic Data.—The physiologic limit of blood-loss compatible with life has been the subject of interesting and extensive study and experimentation from the earlier researches of Herbst (1822) to the present time. The total quantity of blood in the body has been determined approximately by physiologists to be 7.7 per cent. (one-thirteenth) of the body weight. That is, a man weighing 68 kilos (150 pounds) has about 5236 grams or 4965 c.c. of blood in his body, or, roughly, about 5 liters or 5 quarts of blood. In man, death is inevitable when an adult loses at one time one-half (4 to 6 pounds) of the total volume of blood, whereas a more considerable but gradual loss may be followed by recovery. The most severe hemorrhages in surgical opera-

tions very rarely exceed 3 per cent. of the total volume of blood. As a rule, the smaller the animal and the more rapid the hemorrhage, the more severe are its effects. Children are much more susceptible than adults and may die after very small hemorrhages, while women will stand the effects of hemorrhage much better than children or men.

As pointed out by Cabot and others, comparatively slight hemorrhages, which could not impoverish the blood of an adult, may produce considerable anemia.

In the aged or arteriosclerotic from pathologic causes the dangers of acute hemorrhage are still greater, owing to the loss of elasticity and contractility of the vessels and the inability of the diseased arterioles to respond to the call for compensatory vasoconstriction.

Observations upon healthy adults have shown that a loss of about 50 c.c., corresponding to about 250 millions of red corpuscles, is immediately replaced without diminution of hemoglobin or erythrocytes out of the reserve fund of the vascular system (Arneth). Clinical observation, as well as animal experiments, prove that even double or triple the total amount of blood may be lost intermittently in the course of a few months and be completely repaired. Indirectly, this indicates that there exist a constant and extensive formation and regeneration of the corpuscles of the blood in normal conditions, which prepare the organism and compensate it for the losses sustained in hemorrhagic accidents.

Patients recover after the persistence, for weeks and months, of less than 2,000,000 erythrocytes to the centimeter. That the mere deprivation of the oxygen-carrying function of the blood usually plays no essential part in the causation of death from hemorrhage is shown by the fact that in certain chronic hemolytic diseases of the blood, such as chlorosis and pernicious anemia, the erythrocyte count may be reduced to 600,000 or 500,000 instead of the normal 5,000,000 reds (Hayem and W. Hunter), and yet the respiration of the individual will not appear to be perceptibly affected. In a case of acute posthemorrhagic anemia, observed by Dock, the count fell to 357,600 reds per centimeter.

The immediate source of danger from sudden loss of blood is the fall of blood-pressure to a point at which the circulation cannot be maintained. Up to a certain point the effect of the loss of blood on the blood-pressure is completely neutralized by a general peripheral contraction of the arterioles in response to a stimulation of the vasomotor center in the medulla. After very severe and sudden hemorrhage the arterial pressure falls rapidly and suddenly and death will ensue unless means are taken to meet the threatened failure of the circulation. The readiest way in which this can be done, as will be shown in greater detail later, is to replace the lost blood with a certain bulk of fluid. To meet the danger thus arising the amount of blood is more important than its quality (W. Hunter).

The factors that enter into the fall of the blood-pressure and are the essential cause of death in acute hemorrhage are: The sudden anemia of the bulb, vasomotor and higher nerve-centers, which are thus crippled or inhibited, and are unable to regulate the vasomotor mechanism, and

the sudden diminution in the amount of blood circulating in the blood chambers and in the myocardium itself. "Loss of blood predisposes to shock because shock is due to a disturbance of the vasomotor mechanism, and the diminution of the fluid contained in the vessels means an additional tax brought to bear upon the vasomotor center in maintaining a given mean blood-pressure. Every such stress placed upon this center diminishes the total amount of functional reserve it may have."

The effect upon the blood-pressure is most sudden in venous hemorrhage from the large venous trunks because the quantity of blood supplied to the heart is more immediately reduced, the cardiac output being directly proportional to the venous pressure. The blood-pressure is only a quarter of a pound to the square inch in the veins, whereas in the arteries it amounts to four pounds to the square inch, or from ten to sixteen times that in the veins. (See Vol. I., pp. 79 and 922.)

Quantitative and Qualitative Changes in the Blood.—At the very time when the blood is escaping from the vessels there is an effort on the part of the organism to compensate for the diminution of the total bulk by a progressive dilution of the remaining blood to fluid contributed by the tissues. Concentration for the time being is a minor consideration as compared to quantity, for the heart must have something to contract upon in order to prevent an irremediable fall of blood-pressure. Posthemorrhagic blood is hydremic blood, independently of artificial measures (saline infusion) applied to dilute it. The hydremia affects principally the plasma, but Herz found the relative volume of the red cells tripled ten hours after a very severe hemorrhage, indicating that they had absorbed much water (Ewing).

The restitution of the plasma is obtained from at least three sources: (1) From the lymph-stream (greater outpour of the large lymphatic ducts); (2) the more active absorption of water and fluid ingesta from the alimentary canal; (3) the osmotic filtration of the plasma of the tissues into the blood through the walls of the capillaries. The reconstruction of the chemic formula of the blood, especially in the albumin content, requires intestinal assimilation of the proteids contained in the ingesta, which accounts for the longer time required for this process to be perfected and presupposes the integrity of the digestive tract.

The changes in the *morphology* of the blood after traumatic hemorrhage are striking, and are noted in blood examinations more promptly than after the loss of blood arising from pathologic conditions, as in bleeding fibroids, ulcer of the stomach, cancer, hemorrhoids, etc. If profuse hemorrhage is continued for a long period of time or occurs as a sudden great loss, a profound anemia may occur and the regeneration of blood may be rendered impossible. On the other hand, healthy men recover rapidly from moderately severe hemorrhages, and so completely that the red cells may be more numerous than before (policythemia), from apparent overstimulation of the bone-marrow. Diet, purgatives, sweating, and other preparatory measures usually cause a relatively high red count immediately before the operation by the concentration of

the blood. *Summed up in brief, the blood changes are as follows:* A single large hemorrhage reduces the cells in proportion considerably less than the effect upon the volume of blood, beginning half an hour after operation, reaching a maximum effect in three to four days, and followed by a restitution to the normal number in nineteen to twenty-four days (Lyon). The period required for the regeneration of the blood depends upon *age*, the most active period being between the twentieth and fortieth years; and upon *sex*, male adults being the quickest to regenerate, then women and children. Most important, however, is the state of the nutrition. It has been found that a full diet, full supply of water, and intravenous infusion of saline solution greatly accelerate recovery. The immediate effect of hemorrhage is to reduce the hemoglobin-index and erythrocyte count, the color-index dropping with the count on parallel lines. After the hemorrhage is arrested, when regeneration begins, the corpuscles are reproduced more quickly than the hemoglobin, colorless cells abound in the blood, and the color-index is relatively low. As regeneration advances the erythrocytes may exceed the normal as a reactionary phase and then return to the usual standard. The hemoglobin, in the mean time, increases and the standard is restored.

The usefulness of the hemoglobin-index as a guide to operative interference, upon which Bierfreund and Mikulicz at one time laid so much stress, has been considerably exaggerated. Mikulicz laid down the rule that patients showing less than 30 per cent. hemoglobin should not be operated upon. As Deaver very properly remarks, in all emergency hemorrhages the hemoglobin estimation and the red-cell count can scarcely be of any immediate value to the surgeon, since his prime thought, except in lethal cases, is directly to check bleeding if possible, and, as Lazarus says, "the histologic changes peculiar to acute anemia compatible with life are found at the earliest twenty-four hours after hemorrhage." "In symptomatic or chronic anemias occurring with small, but frequently repeated hemorrhages, in association with or as a result of chronic suppurative processes of tumors, the value of the hemoglobin-index and blood-count is to be considered not from a diagnostic but from a prognostic standpoint. Given in these cases a hemoglobin percentage of 25, a paucity of small, distorted red cells, and a diseased, spoiled body, I consider the patient's condition provocative of the surgeon's most serious and sober contemplation" (Deaver).

The most important posthemorrhagic change in the blood is a more or less marked leukocytosis, chiefly of the polymorphonuclear neutrophiles. A severe hemorrhage is usually followed by a rise of the leukocyte count to 30,000 or 40,000. The highest leukocyte count is made almost invariably on the day after the operation (Frazier and Halloway). The blood-plates show a marked posthemorrhagic increase, and it is to this fact that the increased coagulability of the blood in hemorrhage is chiefly attributed.

The Regeneration of the Blood.—The blood is, of all the tissues, most rapidly and completely repaired and regenerated.

The regeneration of blood elements is not effected simultaneously, but in gradual stages, in which the plasma occupies the first rank, the leukocytes and platelets the second, and the erythrocytes and hemoglobin the last. In pathologic states in which the blood-making organs are crippled by infectious processes or degenerative conditions, or in hemolytic processes in which the blood elements are constantly destroyed as rapidly as they are produced, the regeneration of the blood proves abortive (*e. g.*, pernicious anemia, chlorosis) or is totally arrested. In ordinary posthemorrhagic diseases secondary to uncomplicated traumatisms the blood is rapidly regenerated, as in the experimental hemorrhage obtained in normal animals. The mechanism by which the plasmatic deficiency is promptly met by provisional hydremia has already been indicated. The cellular or formed elements of the blood are born chiefly out of the proliferation of the bone-marrow, the germinal centers of the lymphatic nodes (*Keimcentren*, Fleming), the Malpighian corpuscles of the spleen, the liver, and the lymphoid tissue of the intestinal tract, thymus, adrenals, etc. In all these tissues the activity of the proliferative process is directly proportional to the blood loss. In the tissues in which hematogenesis is most active a reversal of type, from the adult to the embryonal form, is observed, as in the bone-marrow (the yellow marrow becoming red), the embryonic nucleated cells (erythroblasts and leukoblasts), which are the product of karyokinetic changes in the parent tissue, often appearing in the blood as nucleated cells long before they have attained maturity. In brief, the regeneration of the blood resolves itself, in spite of its multiform and complex phases, into a simple illustration of the reaction of the living tissues to injury, in which the damage inflicted by accident or disease is repaired, as in all other tissues, by a return of the parent tissue to the embryonal type and its reproduction by the karyokinetic process (Mayer and Heineke).

In surgical conditions it is very seldom that more than 3 per cent. of the blood volume is lost. Therefore, after surgical procedures, the blood should reach its normal within two or three weeks, as far as the regeneration required by hemorrhage is concerned. If the normal is not reached after a traumatic hemorrhage (operative) within three weeks, some pathologic condition, possibly latent, as cancer or tuberculosis, is interfering with complete regeneration (Crile).

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Surgical Varieties of Hemorrhage.—Classification.—Hemorrhage may occur under one of four different forms or all combined, its special designation being derived from the seat of the lesion, namely, arterial, venous, capillary, and parenchymatous.

Arterial Hemorrhage.—This, the most formidable variety, is distinguished by the rapid and copious outpouring of bright red oxygenated blood, which spurts in jets from the injured vessel synchronously with the heart-beat. In the estimation of the color as an index to the source of hemorrhage it must be kept in mind that in deep chloroform anesthesia or partial asphyxia arterial blood may take a purplish discoloration. The diminished output of the heart soon expresses itself by the gradual weakening of the spurt from the wounded artery. The bleeding may be interrupted by compressing the vessel between the heart and the wound, unless there is extensive vascular union by large anastomoses. The blood flows in an even stream instead of in spurts when an arterial lesion is deeply situated, and communicates only by a narrow opening with the exterior.

Venous hemorrhage may be mistaken for arterial hemorrhage when there is an exaggerated local hyperemia, causing the venous blood to look like arterial blood. Exposure to the air of blood escaping from a vein results in prompt oxidation, with the attendant arterial tint. A bleeding vein may be temporarily controlled by compressing the vessel between the capillaries and the wound, whereas the hemorrhage increases in intensity when the vessel is compressed between the heart and the wound, since all the blood is thus made to flow through the opening. Pulsation may be simulated to a certain extent when the bleeding vein is lifted by a neighboring artery, as, for instance, the basilic vein by the brachial artery; or when the intravenous pressure is altered by thoracic aspiration, as in the vessels in the base of the neck (Reclus). Hemorrhage from the large venous trunks was observed by Crile to produce the most profound effect upon the blood-pressure (*vide ante*).

Capillary hemorrhage consists in the oozing of blood from a number of minute points in the exposed surface. This form of hemorrhage becomes a source of danger only through its persistence, since but little blood is lost at each bleeding point. It wells up in a wound like water from a squeezed sponge. Coming from the mucosa, capillary hemorrhage is more serious than from superficial skin wounds on account of the better vascularization of the former. The blood lost in capillary hemorrhage is not as bright as arterial blood, and at the same time is less dark than venous blood. The outpour may be considerable when it comes from inflamed parts under increased blood-pressure (phlegmon); from very vascular organs (tongue, cervix, anus), or when there is a

certain degree of vasomotor paralysis, as after prolonged Esmarch ischemia.

Parenchymatous hemorrhage is characterized by blood of partly venous and partly arterial origin. To a certain extent it coincides with capillary hemorrhage, but occurs also from parts or organs where there is no capillary system proper, minute arteries opening directly into veins, as in the spleen. In other than hemophilic subjects the last two varieties of hemorrhage have a tendency to subside spontaneously by the formation of minute thrombi at the divided ends of the vessels. *Subcutaneous, submucous*, and *interstitial hemorrhages* have already been fully considered.

By the time of its occurrence, hemorrhage is differentiated into (1) *primary*, (2) *reactionary*, and (3) *secondary* hemorrhage. Primary hemorrhage is the immediate result and evidence of vascular injury or lesion appearing under either of the anatomic forms of hemorrhage. *Reactionary* hemorrhage, also called *intermediary* or *consecutive*, is usually the consequence of the return of the blood-pressure after restoration from sudden vascular depletion. The provisional clot formed during the syncopal state, plugging the divided end of the vessel, is swept away. Subsequent to a surgical operation it may occur as the result of slipping of a ligature. The usual time of its occurrence is within the first twenty-four hours following traumatism. *Secondary* hemorrhage is relatively a rare event since the advent of asepsis. Its most common cause is ulceration of the vascular walls, due to septic arteritis. Incomplete repair of the wounded vessel in an aseptic wound rarely is a causative factor. The usual time of its occurrence is between the sixth and fifteenth day after the injury.

Symptomatology and Clinical Characteristics.—The clinical picture of hemorrhage varies enormously, as in the extremes presented by the deadly—almost instantly fatal—outpour from a wound of the aorta, vena cava, or any other trunk of the first magnitude, to the slow but progressive development of symptoms following the extraction of a tooth in a hemophilic subject. Apart from the volume of blood and the rapidity of the flow, which are the essential factors in determining the characteristic symptom-complex of hemorrhage, the age, sex, and condition of the individual in reference to pathologic states greatly influence not only the picture, but the ultimate effects of the hemorrhage. The seat of the hemorrhage or the organ involved in the bleeding gives a special individuality to the symptomatology as well as a distinctive effect upon the organism. The extravasation of a few drops of blood into the medulla may prove instantly fatal; a clot in the brain weighing less than an ounce will cause the gravest and most permanent disorders, while the same amount under the skin will scarcely be noticed. A few ounces of blood coughed up, or vomited, or excreted by the kidneys will create distinctive groups of symptoms which in other localities would attract little or no attention.

Leaving out of consideration the hopeless cases in which death occurs almost immediately after the injury of a great blood-vessel, the uncon-

trolled bleeding from the peripheral artery of secondary magnitude (brachial, superficial femoral), or if we take as examples the hemorrhages which occur in the abdomen, neck, and thorax after penetrating wounds, we shall find a train of symptoms which are typical of acute surgical anemia. The symptomatology in these cases will often be initiated with the first gush of blood and the failure of the first efforts of the patient to arrest it. Fainting will occur, a purely emotional swoon or faint (lypothymia), in which consciousness is lost, but with comparatively slight disturbances in the pulse, heart, or arterial tension. This faint must not be mistaken for true syncope due to cerebral or bulbar anemia, or for the terminal syncope occurring as the last and fatal expression of an irremediable hemorrhage. The initial faint is a purely psychic phenomena of an emotional character which is not at all dependent upon the depression of the circulation. If the patient falls to the ground, lying horizontally, the temporary diminution of the arterial tension will diminish the hemorrhage or even arrest it for the time being; consciousness will soon return and with it the vigor of the heart's action, with a reëstablishment of the hemorrhage as actively as before the loss of consciousness. The true evidences of progressive vascular depletion will now assert themselves. Prostration will follow mere weakness. The anxiety of the patient will increase. Fingers and toes, hands and feet, will become cold, and the entire surface will feel chilled and clammy. The pulse, previously quickened by excitement, will beat faster, becoming smaller and more compressible as the hemorrhage progresses. The temperature will fall steadily, even if there is fever at the time, becoming subnormal as the flow continues. The breathing becomes short, hurried, sighing, and distressed as the patient gasps for breath. A cold sticky sweat breaks out on the forehead and chest and the palms of the drooping hands. Yawning is frequent, in strange contrast with the general distress and grave disturbance in the respiration. Restlessly, the patient throws about his extremities, especially the arms, calling for water to quench an intolerable thirst. At this stage, if the patient will sit up, he may suddenly fall back in syncope, a grave manifestation due to actual reduction of the blood mass, deficient heart action, and lack of vasomotor compensation. In this true syncope the patient's appearance simulates death, the pulse is extremely feeble and beats at long intervals, the respiration is shallow and almost suspended.

In this syncopal state the hemorrhage is arrested and spontaneous hemostasis by coagulation in the wound is most likely to take place. The great retardation as well as shallowness of the pulse-wave favors the formation of a provisional clot, which in the smaller vessels may permanently plug the wound.

If, however, stimulating measures are applied without adequate closure of the vessel, the systolic impulse will increase, the vascular tension return, and the provisional clot will be washed away, followed by a reëstablishment of the hemorrhage. As this progresses the skin becomes waxy, livid, and assumes a cadaveric hue, especially about the

lips, ears, and eyelids. The pupils dilate widely, the sunken eyeballs are thrown about in jerky movements. The mouth gapes wide, the tongue is dry, crisp, and hard from dehydration, the voice is husky. The pulse becomes weaker, more hurried, thready, and irregular. The heart merely flutters in the chest. The arterial pressure drops constantly. Muscular twitchings of the limbs shake the exsanguinated body. If consciousness is retained, the patient is likely to complain of vertigo with nausea and retching; roaring sounds are heard in the ears (tinnitus), dark specks flitter before the eyes (muscæ volitantes), flashes of light, which just before the end are replaced by a deepening pall of darkness. Consciousness is now lost, the pulse flickers, and the respiration assumes an irregular spasmodic or a Cheyne-Stokes type. With these evidences of bulbar failure the terminal syncope with total arrest of the heart's action soon follows, preceded by general muscular twitchings—sometimes general tetanic convulsions, irregular pupillary movements, ending in wide dilatation and fixation, with relaxation of the vesical and rectal sphincters, and death.

Post-hemorrhagic Phenomena.—When the hemorrhage is arrested by timely surgical intervention and the blood loss is small, the patient usually recovers after a variable time, during which the secondary anemia is corrected. In some cases temporary measures may arrest the hemorrhage before the terminal syncope has been reached and death may be thus averted. But if the depletion has reduced the blood to 30, 40, or 50 per cent. of its normal volume, the patient will ultimately succumb in from twelve to forty-eight hours. Unless the blood is reinforced by the infusion of living blood of the same species—mere dilution of the saline solution being inadequate—death will inevitably take place. When the hemorrhage is arrested in the preagonic stage, a patient may recover consciousness temporarily though the mind still remains cloudy. All the signs of acute anemia continue, with dilated pupils, headache, nausea, rapid pulse, dyspnea, arrested secretions, extreme prostration, subsultus, delirium, multiple twitchings, and, finally, death preceded by coma.

Frequently repeated hemorrhages will bring about the same fatal results in the end as observed after one large continuous hemorrhage. In these conditions the malnutrition brought about by the initial hemorrhage is perpetuated by the return of the hemorrhage, which interrupts all efforts at repair and regeneration of the blood. In these conditions there is an "aqueous plethora" and apparently no loss of flesh, the tissues are pale, waxy, and puffy, suggestive of dropsical infiltration or edema. There is exhaustion at the least effort, the pulse is rapid, the temperature is above normal, with periodic remissions and exacerbations. The Hb index and blood-count remain low, and the blood-picture is very much like that of chlorosis. With each successive hemorrhage the pallor becomes greater and the hemic murmurs heard at the base of the heart and throughout the great vessels become louder and louder. Finally, the end comes as a result of progressive exhaustion and perverted metabolism.

Some patients recover from profuse hemorrhages with a violent reaction. There is a general erythism of the vascular system (Hayem). After the arrest of the hemorrhage the heart beats with violence, the pulse is full and bounding—120 and over—throbbing is felt in the temples and subjectively in the peripheral vessels. There is roaring in the ears; phosphenes in the eyes; the head feels full and heavy. The temperature rises above normal ("hemorrhagic fever," which in no case is to be confused with the septic wound fevers) and a state of mental exaltation prevails. The condition of these patients is suggestive of the vascular and nervous erythism observed in exophthalmic goiter. This condition often occurs also as a prodrome or precursor of a recurrent hemorrhage.

Differential Diagnosis Between Hemorrhagic Collapse and Shock.—In the emergencies of surgical practice a differentiation between these two conditions, or even the preponderance of one over the other, is extremely difficult; this difficulty being felt especially in those cases of suspected concealed hemorhage in which the early differentiation would be helpful to the surgeon. The distinction made by Crile (Vol. I., p. 922) between shock and collapse—viz., that shock is essentially a paralysis or, at least, an exhaustion of the vasomotor center, while in the collapse of hemorrhage there is no such exhaustion, but merely a suspension or inhibition of function—is of no help practically, because the two conditions when viewed in typical cases are clinically identical. Even syncope, which is distinguished from collapse or shock by sudden loss of consciousness, dependent upon the retreat of the blood from the brain, due largely to psychic influences, is difficult to distinguish from either shock or collapse, especially when associated with injury.

The differentiation between the collapse or syncope of hemorrhage from shock is most important in critical cases in which concealed progressive hemorrhage is suspected, as in the great traumatisms, gunshot-wounds of the abdomen and thorax. In these cases prompt action is required to save life, and yet the surgeon is often perplexed and hesitates, unable to decide whether he should interfere or not. If hemorrhage is the cause of the collapse, there is evidently no time to lose in opening the cavity and securing the bleeding point at once. If shock is the dominant condition, a formal laparotomy would only add to the gravity of the case. When the condition of the patient is such as not to justify delay for observation, the only course left to the surgeon is to proceed as if he were dealing with hemorrhage. In these extreme cases the patient will rally and react immediately after a hot intravenous saline infusion if hemorrhage is the dominant element. On the other hand, if there is no hemorrhage and shock is the essential element, as seen in the great visceral traumatisms, and in cases of profound and overwhelming sepsis, there will be no reaction, no circulatory response, or at least such as will give the pulse sufficient volume and stability to warrant the operator in proceeding with an exploratory operation. This sort of therapeutic test I have found more reliable than any other in practice, though I find that with increasing ex-

perience the application of saline infusion as a test has become less frequent than in former years. In less acute cases the differentiation of hemorrhage from shock will be assisted by the blood examinations, which will show a steady fall in the red blood-count, with a reduction in the Hb index. This, in connection with the history of the case, a steadily rising pulse and falling temperature, will help to differentiate the two conditions. Furthermore, if there is progressive hemorrhage in the abdominal and thoracic cavities, the development of physical signs, such as increasingly dull areas on percussion corresponding to the seat of the blood accumulations, will help to clear up the diagnosis. But in practice the duty of the surgeon when in doubt as to the existence or progress of hemorrhage is to proceed directly to the exploration of the suspected region, as, for instance, the abdomen, where, by a small incision, under local anesthesia, he will be able to determine quickly the true nature of the case. When there is no immediate urgency, as in some early cases of extra-uterine pregnancy, in some forms of threatened perforation in typhoid, or in acute peritoneal sepsis which may be confused with hemorrhage, a surgeon may avail himself of blood examinations to determine the Hb index and blood-counts, made at short intervals, as valuable helps in arriving at conclusions.

"A large internal hemorrhage, as from a ruptured extra-uterine gestation sac, or ruptured spleen or kidney, or ulcer of the stomach or duodenum, causes a loss of red corpuscles and induces a leukocytosis. When such blood changes are noted, they are valuable in differentiating the conditions attended by hemorrhage from intestinal obstruction or peritonitis. Cerebral hemorrhages can be differentiated from concussion of the brain by the concomitant leukocytosis. The leukocytes may rise in number as high as 20,000. A mild degree of shock calls forth a slight rise in the number of leukocytes. *Severe shock paralyzes the leukoblastic tissues temporarily, as a result of which a transient leukopenia ensues.*"

It is important in interpreting the significance of leukocytosis in post-hemorrhagic cases not to overlook the fact that many drugs (potassium iodid, quinin, salicylic acid and the salicylates, antipyrin, protonuclein, digitalis, morphin) all cause a leukocytosis. Ether and chloroform have a vigorous hemolytic action, which is followed by polycythemia from overstimulation of the blood-making organs. On the other hand, it is followed by a comparatively high reactionary leukocytosis (average 30 per cent.), more than before anesthesia (DaCosta), the rise occurring during anesthesia and lasting about twenty-four hours. Purgation and saline infusion are also followed by a leukocytosis which may prove deceptive.

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Prophylactic and Provisional Hemostasis.—The numerous resources for the prevention of hemorrhages are among the greatest contributing factors to the development of modern surgery. Indeed, of all the operative causes of shock, admittedly the first and chief is hemorrhage, then pain, and injuries to the nerves. "The older the surgeon, the greater becomes his respect for a drop of blood" (Dawbarn).

Among the agents to be considered in prophylactic hemostasis besides the constitutional measures which affect the blood-pressure, the contractility of the peripheral blood-vessels, or increase the coagulability of the blood are the following:

Position.—Elevation. It is through the vasomotor system that the influence of changes of position on the circulation is almost completely compensated, especially in man and those animals to which the upright position is normal. While in normal men and animals the influence of gravity is largely neutralized by the compensatory mechanism of the vasomotor system, it is well known that this compensation is lost in a great measure when the vasomotor center in the medulla is inhibited, weakened, or exhausted by conditions which affect the intracranial circulation, acute anemia from hemorrhage, shock from extensive traumatisms, powerful emotional influences, the circulation of the toxic agents in the blood (chloroform, ether, bacterial toxins, etc.), exhaustion, and malnutrition from disease. In the constant play between the hydrostatic and hydrodynamic factors (heart and vasomotor nerves) the equilibrium of the circulation is easily disturbed by any element which will weaken or diminish the sensitiveness and energy of the vasomotor center which is constantly adjusting the differences in the blood-pressure caused by position and gravity. A knowledge of these elementary physiologic facts is of almost daily application in hemorrhage. The influence of general anesthesia, by chloroform or ether, as well as of the great surgical infections, is most marked in its weakening effects on the vasomotor centers, and, therefore, when utilized judiciously, is a most valuable agency in obtaining postural anemia as a prophylactic of hemorrhage. Elevation of a bleeding part is not only a valuable hemostatic in preventing but also in controlling hemorrhage. *Elevation of the head and trunk* has a most potent influence in draining the blood supply away from these parts. No operating-table is complete without provision for the "head-up" position. In cranial, facial, and cervical operations, if the patient is tilted up to an almost upright position, a relative "*gravity anemia*" will be obtained proportional to the degree of elevation and depth of anesthesia. In this way the blood supply to the brain will be notably diminished and the hemorrhage from the elevated parts will greatly lessen; at the same time the amount of anesthetic required will be much less than would be needed in a horizontal position.

Prophylactic hemostasis is also advantageously obtained in *pelvic* and *sacral operations* by elevating the pelvis with the thighs flexed or by the extreme Trendelenburg or Sims' positions. Senn has especially

demonstrated its value in extirpation of the rectum by the Kraske or the perineal routes.

Vertical elevation of the bleeding part will often quite suffice to control bleeding in wounds of the foot, leg, or forearm. The benefits of the elevated positions can be supplemented in many cases, in both the upper and lower extremities, by combining pressure with *flexion*, which offers an additional impediment to the peripheral circulation. Thus, the leg should be flexed on the thigh and the thigh on the pelvis at an acute angle. In the upper extremity, by extreme extension of the arm on the shoulder-joint backward, and flexion of the forearm on

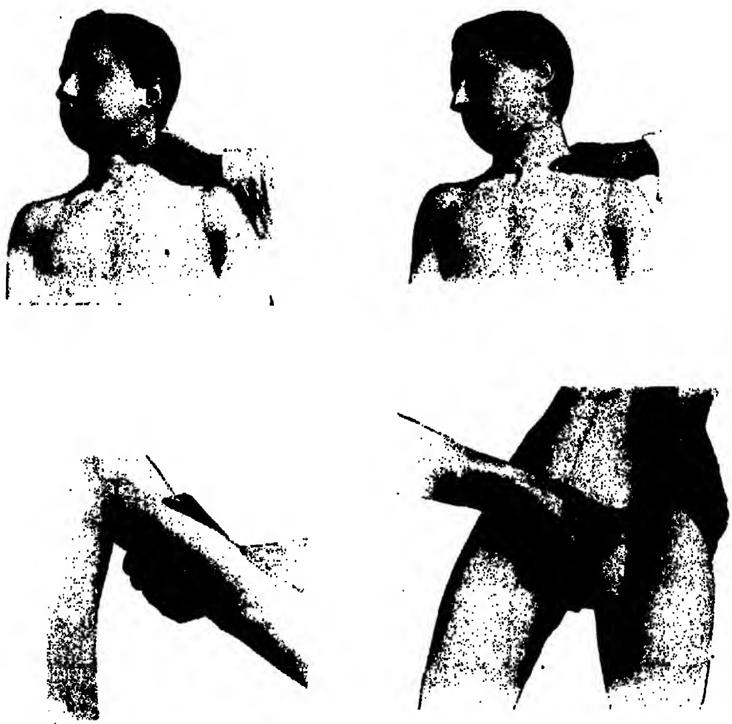

FIG. 64.—*a*, Digital compression of carotid artery; *b*, subclavian artery; *c*, brachial artery; *d*, femoral artery. (Marwedel.)

the arm, the bleeding in the distal areas of the extremities will be practically controlled. In severe hemorrhages, from comparatively large vessels at or near the root of limb, elevation and flexion are of little value and must yield to more reliable measures.

Pressure.—Whether *directly* or *indirectly* applied to control a bleeding surface, pressure in its numerous forms of application is the most generally available and efficient agent for the control of hemorrhage. As a mechanical principle it is the basis of digital or manual compression, of the elastic bandage, the constrictor, or the tourniquet; the tampon or pack, forcipressure, angiotripsy, acupressure, the ligature,

and the suture; therefore, as a fundamental method, it rightly stands first.

Bleeding from a wound, whether arterial, venous, or capillary, may be promptly controlled by *immediate compression*, exercised with the fingers inserted in the wound and *directly* against the bleeding point. *Direct digital compression*, which is the simplest, quickest, and most certain of the provisional hemostatics in all accessible wounds, can be replaced by compression of the afferent artery which supplies the region involved in the hemorrhage. Thus, in wounds of the neck the *common carotid* may be controlled by energetic pressure on the vertebral column opposite the transverse process of the sixth cervical vertebra (Chassaignac's tubercle), by forcing the tips of the fingers on the artery at this point to the inner side of the sternomastoid muscle (Fig. 64, *a*). The *subclavian* can be compressed, in subjects that are not too stout, in the third part of its course by forcing the thumb vigorously on the artery as it rests on the first rib behind the clavicle, while the palm of the free hand of the operator forces down the corresponding shoulder. At the same time the sternomastoid is relaxed by turning the patient's face away toward the opposite side of the injury (Fig. 64, *b*). The *brachial* can be controlled by pressure in the upper arm (Fig. 64, *c*).

FIG. 65.—MACEWEN'S METHOD FOR COMPRESSION OF THE ABDOMINAL AORTA. (Keen and White.)

The *common femoral* is most superficial under Poupart's ligament, where it can be readily compressed by the fingers, which jam it back upon the pubic ramus directly in the groin (Fig. 64, *d*).

It was at one time recommended that the *common* and *internal* iliac arteries be compressed for prophylactic hemostasis by the fingers after the hand has been introduced into the rectum (Woodbury) or with a lever (Davey); but these methods were so unsurgical, unsatisfactory, and unreliable that they promptly yielded in the aseptic period to the method of intraperitoneal compression of the artery with the fingers (McBurney, 1897; Battle, 1898) or with provisional clamps or traction

loops whenever digital compression is indicated for the control of hemorrhage in the territories supplied by the iliac arteries.

Compression of the aorta by Macewen's method is applied by throwing the weight of the body on the abdominal aorta, as it rests upon the vertebral column, through the closed right fist of the operator placed a little to the left of the middle line, the knuckles of the index-finger just touching the upper border of the umbilicus (Fig. 65). Only enough pressure is required to stop the femoral pulsation at the groin. This method is only applicable to very thin patients with relaxed abdominal walls or aided by general anesthesia. It is often unreliable.

Momburg's Method of Obtaining Ischemia of the Lower or Infra-umbilical Half of the Body by Circular Elastic Constriction.—In June, 1908, Momburg, of Spandau, described a simple method of performing bloodless operations on the pelvis, hip, and lower limbs by an elastic circular (mediate) constriction of the abdominal aorta. His technic is very simple. The waist of the patient is encircled by a heavy rubber tube placed midway between the costal arch and the iliac crests. The rubber tube should be as thick as the finger, should be stretched to the utmost limit of extensibility, and wound around the trunk from two to four times until all pulsations are arrested on the femoral arteries at Poupart's ligament. The constriction should be applied after the patient is completely relaxed by a general anesthetic. To obtain ischemia of the pelvic regions, Momburg advises that a preliminary anemia of the lower extremities be obtained by applying the Esmarch bandage from the toes to the groin. Then the abdominal constrictor is applied, the Esmarch bandages are removed, and the limb allowed to hang from the edge of the table, so that the pelvic blood that remains may gravitate to the extremities. The blood thus displaced is retained in the limbs by applying an elastic constrictor at the root of each. The bowels should be well emptied before the operation. This method of abdominal constriction has been kept up for forty-five minutes and over without ill effects on the intestines. Apart from a temporary rise in the blood-pressure and pulse, while the constrictor is in situ, and a fall in the blood-pressure when it is removed, no untoward ill effects attributable to the method have followed. It is especially adapted to operations in thin, relaxed, weak subjects. In 9 cases recently reported by Willems the method has proved reliable and satisfactory.

In all cases where digital compression is applied to the larger vascular trunks, the efficiency of the compression is tested by the arrest of pulsation in the artery immediately below the point of pressure or by the cessation of hemorrhage in the wound.

Circular constriction, directly over a pad of aseptic gauze packed into the wound, is of all the methods of hemostasis by far the most certain and of more general application, either as a preliminary to operation or in accidents while transporting the wounded or waiting for more definite surgical action. When an elastic bandage is not at hand, a tourniquet can be extemporized (as taught in all "First

Aid Manuals") by encircling the limb with a cord, rope, strap, suspender, or strip of cloth torn off from the patient's shirt, bed-sheet, etc., the ends being knotted over a club, walking stick, sword, knife, bayonet, umbrella, etc., the encircling band being tightened by turning the stick on the principle of a Spanish windlass until the bleeding stops. More efficient still in emergencies is to wind a piece of elastic tubing, rubber gas-pipe, or tube of a fountain syringe several times around the limb on the proximal side, stretching the tubing as each turn is made, and finally tying or clamping the ends so that these cannot slip. In military practice, the first-aid package furnished to every soldier in civilized countries provides the necessary materials for a sterile hemostatic pack or compress, the soldier's strap being utilized as a tourniquet. The Esmarch bandage is preferable to all these makeshift contrivances, because the pressure exerted by it is more uniform and extends over a large surface. In surgical practice the Esmarch elastic constrictor or its derivatives have entirely supplanted the numerous special tourniquets and mechanic contrivances which still figure in the older surgeries and in the instrument-makers' catalogues.

The Esmarch Method.—This consists in the application over the limb of an aseptic elastic rubber bandage after the limb has been sterilized and covered with a soft towel wet with bichlorid (1: 1000) or carbolated (2½ per cent.) solution, which is wrapped around the affected limb. The elastic bandage is applied tightly, from below upward, in an even spiral (without reversing), and is carried as high as is desired. The blood is all driven out of the vessel as the bandage is adjusted. Immediately above the upper terminus of this elastic roller a rubber band or hollow elastic tube is wound several times around the limb with sufficient contracting force to arrest entirely all arterial pulsation below. The constrictor is then held in place by tying it or by a clamp. After the constricting bandage is secured, the elastic roller is removed and the limb below the constriction shows a characteristic pallor which markedly contrasts with the healthy ruddiness of the parts above. The operation can then be performed precisely as upon a cadaver, and is absolutely bloodless.

In applying the elastic constrictor or tourniquet at the root of the limb the following precautions should be observed: (1) Never apply the constrictor over the leg or forearm, as the interosseous vessels are protected from pressure by the two bones of these regions, and hemostasis must be imperfect. Always apply the elastic tourniquet over the femoral or humeral shafts, or at such points that no vessel can escape a circumferential compression; thus, in the lower third of the femur just above the condyles the rigid abductor magnus tendon may interfere with the complete compression of the femoral. (2) In applying the elastic tourniquet begin by compressing the vascular or adductor side, leaving the outer or extensor surface of the limb free from pressure, so that venous choking of the limb may be avoided. This precaution is especially important when the limb is drained of blood by elevation. (3) While encircling the elastic band, it is necessary to avoid repeated constriction on the same level (linear constriction), as an exaggerated concentric compression, in thin subjects especially, may permanently paralyze the extremity by

crushing the underlying nerve-trunks and vessels. Therefore, separate each turn of the rubber by an intervening space, so as to distribute the pressure. (4) Do not allow the constricted member to be suddenly flexed or extended after the constrictor is in place, for fear of tearing subcutaneously the underlying muscles and nerves. (5) Do not keep the constrictor in place much longer than an hour or an hour and a half, because sloughing from prolonged arterial fasting and coagulation necrosis of the muscle in the distal parts may take place, causing the very serious deformity known as Volkmann's contracture; or the flaps, in aged or weakened subjects, may slough. This is especially true of operations performed with local or regional anesthesia, in which the constrictor is likely to be retained longer for anesthetic purposes.

FIG. 66.—PROPER METHOD OF APPLYING THE ELASTIC CONSTRICTOR. (Senn.)

The *length of time* the constrictor may be allowed to remain in place without danger or damage to the tissues is quite variable. Half an hour's constriction in some cases (very much inflamed and infected limbs, and in arteriosclerotic subjects, diabetic gangrene, and other conditions in which the arterial supply has been long impeded by vascular disease) may end in gangrene of the peripheral parts. In others, simple aseptic necrosis of muscular bundles will take place, leading to final contracture and rigidity of the extremity. In fairly healthy robust subjects an hour or even longer (Esmarch, two and one-half hours) is permissible, but it should be remembered that every additional hour after the first adds to the risk of permanent damage to the extremity from protracted anemia. It has been objected with good reasons that the ischemia of a limb obtained by forcible

elastic compression (Esmarch's method) is likely to be followed by (1) Excessive capillary oozing, requiring an undue manipulation and irritation of the injured tissues to control it, as well as the ligature of many more vessels than usual. This is due to vasomotor paresis of the compressed area and can be corrected by the stimulus of very hot water applied to the cut surface and by stroking or superficial massage of the limb. (2) It increases the risk of septic embolism and of cancerous metastasis by forcing particles from the diseased area into the venous and lymphatic circulation. (3) It greatly favors the absorption of toxic chemical antiseptics (Wölfler's experiments). (4) It increases the liability to ischemic necrosis.

Gravity Ischemia with Elastic Constriction.—These objections have led to the application of the Esmarch rubber tourniquet alone, which secures satisfactory ischemia without the preliminary elastic compression of the entire limb. Instead of applying the elastic bandage, the limb is elevated and held up as near the perpendicular as possible, so that the blood is drained out by gravity (Fig. 66). While the limb is being held up it is stroked vigorously from the tip of the extremity (fingers or toes) to the trunk; this process ("milking" the limb) is followed by the application of the elastic constrictor at the root of the ex-

FIG. 67.—SHOWING APPLICATION OF ELASTIC CONSTRICTOR TO THE HIP. (Marwedel.)

tremity, when it is evident by the pallor of the skin that it is sufficiently exsanguinated. This method is very efficient and, owing to its freedom from the objections urged against elastic compression, is always to be preferred in debilitated subjects of low vitality and with impaired peripheral circulation.

Sequestration Anemia.—With the same object in view, Dawbarn, of New York, has recently suggested what he appropriately designates as "sequestration anemia," by which a part of the blood mass is retained in the extremities in sufficient quantity to diminish the general blood-pressure at will. "Experience shows that we can, with entire safety, withdraw into the limbs some quarts of the whole bulk of blood which constitutes one-thirteenth of the individual weight. We can 'sequestrate' before operation and retain in the limbs, *by cordage*, enough to make a striking difference in loss of blood in the operative field." Dawbarn's technic is as follows: "A towel folded lengthwise is wrapped about each thigh very close to the trunk, and upon it the rubber constrictor is tightened. The degree of tightness is quickly learned by

practice. It must nearly stop the venous, but not the arterial, current. Quickly the limb distal to the tourniquet grows dusky in color and there is obvious swelling also. After some five to ten minutes the softened pulse will indicate that we are ready to proceed with the operation.'" The claims made for sequestration anemia are: "That it markedly lessens hemorrhage in operations on the head and neck; lessens the time of operations because of diminished bleeding; greatly diminishes the amount of anesthetic taken because of the anemia of the brain."

The **aseptic** and **antiseptic tampon** is a provisional and often permanent hemostatic procedure of frequent application in surgical practice. It consists in packing the bleeding wounds of cavities which are not readily amenable to the ordinary means of vascular control with pieces or strips of sterile or antiseptic gauze, which are systematically packed and made to fit every irregularity of the wound or cavity, the finger or forceps being used for this purpose. After the packing is done and the bleeding arrested, the pack may be held in place by a provisional suture in the lips of the wound, leaving a terminal end projecting beyond the wound to facilitate its extraction. The nasal tampon for epistaxis; uterine tampon for metrorrhagia; the Mikulicz tampon in the abdomen and pelvis to check the oozing following torn adhesions; packing of the bladder with an inverted "umbrella pack" of gauze after suprapubic prostatectomy; the hemostatic pack of the cranial sinuses; the compression of the lung by an intrapleural pack in wounds of the chest (DaCosta), and of the pelvic and abdominal organs, when copious capillary or parenchymatous hemorrhages cannot be controlled by direct ligature or suture methods, are all illustrations of the provisional and permanent application of this excellent procedure in surgery.

Heat, in the form of hot and boiling water, the actual cautery, galvanocautery, and steam, is a most valuable hemostatic agent.

At present it is only used as a destructive agent or caustic in the removal of small growths, in controlling parenchymatous and capillary bleeding, in visceral wounds, or in tissues in which the raw surface is likely to remain exposed to infection. In this way the Paquelin cautery and galvanocautery are still largely used in nasal, laryngeal, dermatologic, and rectal practice. In combination with the crushing of the tissues, vascular pedicles of tumors, hollow organs, etc., its use is exhibited in the Downes' galvanocautery clamps (Fig. 35). By crushing and burning the tissues of a pedicle the mass to be divided is not only sterilized, but is reduced to a fine thin membrane which is easily secured by a small ligature, thus eliminating the heavy massive ligatures of the past. The object of the cautery in arresting hemorrhage is to make an eschar deep and strong enough to resist the blood-pressure. To accomplish this it must be used at a dull-red heat (cherry red), which penetrates and cooks the tissues slowly and thoroughly. The eschar once formed, must not be disturbed, as its premature removal is sure to be followed by hemorrhage, especially in the parts subjected to much disturbance or motion, as in the rectum (hemorrhoidal area). It cannot be relied upon in hemophilic subjects,

or whenever vessels of any importance are involved in the cauterized areas, because secondary hemorrhage is likely to follow after the fall of the eschar. Wounds treated by this form of cauterization necessarily heal by granulation.

Hot water, if below the boiling-point, not too hot for the naked hand to bear without scalding, acts by stimulating the unstriated muscular fibers of the blood-vessels to contraction. The hemostatic effect is increased by pouring hot saline solution, in a large stream from a pitcher, at some height over the surface of the wound.

The value of heat in the form of hot saline solution introduced by intravenous infusion to stimulate a flagging heart is universally recognized. For controlling arterial and capillary cerebral hemorrhage Victor Horsley relies on hot-water irrigation at a temperature which should not exceed 115° F. nor fall below 110° F. He fears that if 120° F. be used, heat coagulation of the cut surface of the brain will result. Dawbarn has found that nerves are not especially affected by a few seconds' contact with boiling water. Dawbarn is most emphatic in his recommendation of boiling water—not merely hot, but water at 212° F. After operations in which much capillary oozing is feared, before relaxing the constrictor he covers the field with gauze sponges wrung dry with a rubber-gloved hand out of actually boiling water brought at the moment to the operating table. "No one need fear ill results to even the most delicate tissues of the human body from a few seconds' application of gauze at this degree of heat—the brain perhaps excepted—and in consequence, not only is bleeding prevented, but the entire raw surface turns white from coagulated albumin, sterilizing it as it was not sterile before." On the other hand, it is evident that a degree of heat applied to a raw surface sufficient to coagulate the protoplasm of the tissues must necessarily impair the resistance to infection, so that if this occurs, as is inevitable on large surfaces, the chances of primary union may be greatly impaired. Hot water, not boiling, will, however, produce no necrogenic effects and will accomplish practically as much good if combined with firm pressure over the dressings in arresting capillary oozing.

Atmokausis.—This name is applied to a procedure consisting in the spraying of steam upon the bleeding surface. It was introduced by Snegireff, in 1886, for the management of parenchymatous hemorrhages. It has been especially used in gynecology. The occurrence of deplorable accidents, excessive sloughing, from inability to regulate the depth of penetration, have circumscribed its application to special practice. During the performance of atmokausis, steam is given free access to the uterine mucosa through a fenestrated catheter. When this tube is not perforated, it becomes heated by the steam circulating within it, and serves for contact cauterization or zestokausis. The terms atmokausis (*atmos*, steam, *kausis*, burning) and zestokausis (*zestos*, to boil) were introduced by Pincus.

Cold.—The application of cold as a hemostatic is much more restricted than that of heat. Cold in any form has the same effect on the

blood-vessels as its counterpart, heat, that is, it produces contraction of the blood-vessels. Cold is employed in the form of ice, ice-bags, cold water, and vaporizing sprays of ether and ethyl chlorid. Ethyl chlorid spray to freeze a tooth-socket has been used with benefit in arresting obstinate hemorrhage after extraction. After clearing out the blood-clot, the socket is frozen and cotton soaked in gelatin-adrenalin solution or iodoform gauze dipped in the same solution, or 10 per cent. antipyrin solution (DaCosta) applied. Cold is contraindicated in cases of hemorrhage complicated by shock and should be avoided in acute anemia with subnormal temperature.

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TREATMENT OF HEMORRHAGE.

The three fundamental indications to be observed in the treatment of hemorrhage are: (1) Arrest the bleeding; (2) prevent its recurrence; (3) aid the organism in recovering from the effects of the hemorrhage and in the restoration of the blood to its normal standard of efficiency.

In meeting these indications, *local* as well as *constitutional* measures will be required, as shown in the previous section.

In meeting the *first* indication the bleeding point, if at all accessible, should be at once sought, exposed, and secured by forcipressure, ligature, suture, etc. (See Surgery of Arteries and Veins.)

The *second* indication is met by adopting a careful technic and, above all, by observing a very rigorous asepsis in the management of the wound, or by applying such measures as will minimize or neutralize any existing infection. The *third* indication will now be considered.

Constitutional or Systemic Treatment.—The object of the constitutional treatment may be considered from three points of view: (1) As an aid to natural or spontaneous hemostasis, as in all internal hemorrhages in inaccessible organs and cavities where direct surgical interference is impracticable or unjustifiable (hemoptysis, gastrorrhagia, enterorrhagia, and typhoid hemorrhage; hemothorax from gunshot wounds of the chest, etc.); (2) as a stimulating or restorative treatment after the hemorrhage has been arrested, the patient still being prostrated from the immediate collapse and shock; (3) after the recovery from the immediate effects of vascular depletion, as an aid in

the regeneration and restoration of the blood to its normal quantity and quality.

It is evident enough that little can be expected from general treatment until the hemorrhage has been permanently arrested; and the administration of stimulants and restoratives is absolutely contraindicated until the hemorrhage is under control. The following principles laid down by Senn clearly voice the right teachings of surgery: (1) Any treatment calculated to increase the heart's action and to intensify the vascular pressure must be carefully avoided; (2) stimulation is in order and is urgently called for when the patient is much prostrated from the loss of blood and further bleeding has been guarded against by effective hemostasis; (3) in surgical cases in which the patient is evidently bleeding to death and is almost pulseless from circulatory collapse, it is perfectly in accord with the best practice to proceed with prompt stimulation (intravenous saline solution), with the view of reviving the patient while the effort is being made to secure the bleeding point. In non-surgical hemorrhages, where no intervention is possible, as previously stated, stimulating treatment would be absolutely illogical and fatal.

In approaching the treatment of all grave hemorrhages the circumstances in which they occur must be considered. In the great accidents of life, as in machinery accidents, stabs and gunshot wounds, personal encounters, murderous assaults, etc., the blood loss is usually associated with nervous shock, and it is difficult if not impossible to separate the two. In accidents the surgeon must immediately arrest the hemorrhage as the first and vital indication. After this, caution and deliberation are necessary. There should be no undue haste in moving a wounded man, in applying dressings, and in operating. Absolute immobility is the first therapeutic indication.

Ordinarily, patients who have suffered great loss of blood are found lying horizontally; if not, they should be laid on their back, with the head low, with the feet and arms raised to favor the flow of the bloodstream to the brain and medulla, where it is most needed to rouse the vasomotor centers and the heart to activity.

Autotransfusion.—The "Nélaton position," in which the body is inverted with the head low down, is a form of autotransfusion by which the force of gravity is utilized in directing the blood to the heart and head. A certain amount of autotransfusion can be obtained by elevating the foot of the bed so as to incline the body, with the head down, at an angle of 45 degrees (a reversed Fowler position). By Hunter's method blood is forced into the trunk and head by bandaging the extremities firmly from the digits to the root of the limbs. If an elastic bandage is at hand, each extremity, after it has been thus exsanguinated, can be made bloodless and the blood excluded from it by a circular constrictor or tourniquet applied to the root of the limb. In this manner, according to the severity of the symptoms, one, two, or all of the extremities are excluded from the circulation long enough to gain sufficient time for the application of the more permanent therapeutic measures.

In the operating-room this form of autotransfusion can be applied by the use of Crile's pneumatic suit. (See Vol. I., p. 939.)

In accidents, all tight clothing should be removed, especially about the neck and chest. *Fresh air* is instinctively called for; therefore, every impediment to the admission of fresh air should be removed. *Oxygen* is indicated in all acute hemorrhagic anemias and should be freely supplied. *Artificial heat* to the extremities, precordia, and head is needed. Woolen blankets, hot-water bags, hot bottles, hot bricks, and in hospitals, the electrothermic bed-pads or the hot-water pads (Goodrich) are most useful. These external measures are effectively assisted by hot *stimulating solutions* injected slowly into the rectum—strong *black coffee* being especially available and beneficial. The formula for post-operative shock, acute anemia, or exhaustion usually prescribed by myself is: Black coffee, 8 ounces; panopepton, 1 ounce; brandy or whisky, 1 ounce; tincture of digitalis, 15 minims; laudanum, 10 minims; to be administered slowly and repeated every two hours if the case still calls for it. Champagne, whisky, or brandy, which are as diffusible by rectum as by stomach, may be freely given by enema, diluted with physiologic salt solution or combined with other ingredients, when for any reason they cannot be taken by the normal route.

Medicinal Agents.—Remedies having a favorable effect in rousing the heart and improving the arterial tension (after the bleeding has been controlled) are: Strychnin (nitrate or sulphate), gr. $\frac{1}{60}$ to $\frac{1}{20}$; digitalin (American), gr. $\frac{1}{60}$ to $\frac{1}{15}$); digalen (Cloetta), hypodermically, 0.5 to 1 c.c.; tinct. of digitalis, standardized and fat free, 10 to 20 min.; atropin, gr. $\frac{1}{200}$ to $\frac{1}{100}$); spartein, gr. $\frac{1}{3}$ to 1, in large doses, as recently recommended by Stuart McGuire; fluidextract of ergot, 1 dram; or ergotin, gr. 1 to 2, all of which are given for their effect upon the heart muscle, the blood-vessels, or the brain, with the view of increasing the strength of the heart or improving the blood-pressure by general peripheral contraction.

Adrenalin, in the form of a solution of 1:1000, may be given by direct intravenous injection with a fine needle inserted into a superficial vein through the skin; the dose is from 5 to 20 minims. It is often given by mouth or subcutaneously, but recent investigations (Dixon, Janeway, Elliott) show that it is rendered inert in the stomach and never reaches the circulation. Under the skin its action is purely local; for this reason it can never be used effectively except by intravenous injection. In addition, camphorated oil in 20-minim doses, frequently repeated, and caffein benzoate or citrate (gr. 1) may be of service.

In administering these various circulatory stimulants, it is important not to begin by giving massive or maximum doses, but to administer comparatively small doses frequently repeated. In the excitement incident to a great hemorrhage the inexperienced often give massive doses, which are repeated at short intervals with cumulative and toxic effect. In this way a critical situation is often complicated by powerful drugs, which overwhelm the feeble and struggling patient. On the other hand, the judicious administration of circulatory stimulants is undoubtedly a powerful adjunct to other means of treatment.

In hospital and operating-room practice, when frequent stimulation is required to strengthen the flagging heart, combinations of the drugs mentioned in different groups are given alternately, so that the same drug is not repeated oftener than every two hours. Thus, a hypodermic of digalen, 20 min.; strychnin, gr. $\frac{1}{40}$; atropin, gr. $\frac{1}{200}$; nitroglycerin, gr. $\frac{1}{500}$; followed in one hour by a hypodermic of caffein, gr. 1; fluidextract of ergot; or, preferably, a sterile standardized extract of ergot (ergotele, ergone, or ergotin), gr. 1, given by needle. In the next hour, spartein sulphate, gr. $\frac{1}{3}$, is given. In the intervals between these doses hypodermics of camphor oil, 15 to 20 min., and occasionally (not once in my own practice) hypodermic injections of ether and dilute alcohol. By mouth, champagne, whisky and brandy toddies, and black coffee may be given. In all cases in which there is much psychic shock or painful injury the addition of $\frac{1}{8}$–$\frac{1}{4}$ grain of morphin to a stimulating hypodermic is a most valuable adjunct.

But above all these drugs, and of far greater importance, is the free administration of water, cold or hot, or of cracked ice. If the patient can swallow, water is usually taken with avidity. Its use should never be restricted, as it is rapidly absorbed and acts as a normal infusion *per vias naturales*, helping to fill the depleted vessels.

In the very grave cases of collapse, in which the pulse becomes almost imperceptible and life is nearly suspended, no time should be lost in resorting to the most powerful of all life-saving measures, *intravenous saline solution.*

Saline infusion, with the sole exception of direct blood transfusion, is by far the most reliable of the general or constitutional restoratives in the treatment of hemorrhage. Since it has been ascertained that the grave phenomena of post-hemorrhagic anemia, and death itself, are not due to the loss of corpuscular elements, but to the mechanic disproportion between the area of the vascular system and its content, attempts have been made to raise the lowered intravascular tension by the injection of variable amounts of indifferent fluids, from plain distilled water to complex imitations of the normal human blood serum. It was shown, however, that plain distilled water is very destructive to the red corpuscles, which it swells and breaks up with fatal consequences (W. Hunter, Kronecker, *et al.*). But they remain uninjured if a certain amount of salt (sodium chlorid) is added to the water.

The normal or, more correctly, the decinormal salt solution—6 parts of table salt per 100—approximates the saline strength of the blood-serum. In practice, this means about a heaping teaspoonful to the quart of boiled and filtered fluid, or $\frac{2}{3}$ of a dram (40 grains) to a pint of sterile water. This solution is "normal," not in the chemic sense of the term, but in the physiologic—*i. e.*, corresponding with the proportion of sodium chlorid in the blood (isotonic). Normal saline solution contains enough sodium chlorid to prevent hemolysis of the red corpuscles, namely, 0.6 to 0.7 per cent., and has been demonstrated to be, for all practical purposes, the preferable solution (Carrion and Hallion).

Various modifications of the normal saline solution have been proposed and tried, among which Ringer's and Locke's solution deserve special mention. Ringer's fluid is made up as follows: Potassium chlorid, 0.2 gm.; sodium bicarbonate, 0.2 gm.; sodium chlorid, 9 gm.; and distilled water to make 1 liter. Locke's fluid (more satisfactory in its effects) has the following formula: Distilled water, 1 liter; sodium chlorid, 9 to 10 gm.; calcium chlorid, 0.20 gm.; potassium chlorid, 0.10 to 0.20 gm.; sodium bicarbonate, 0.10 to 0.20 gm.; glucose, 1 gm.

The saturation of saline solution with oxygen immediately before its introduction into the circulation by the intravenous route would appear to be especially indicated in all grave hemorrhagic cases. Küttner's solution is equivalent approximately to 20 c.c. of gas to every 1000 c.c. of the fluid.

The proper temperature for the infusion fluid is as hot as the hand can bear, about 120° F. or 49° C. (Dawbarn) in the container. This temperature, higher than usually recommended, is very stimulating to the flagging heart and maintains the tone of the muscular tunic of the vessels.

Larger quantities of saline solution are required and tolerated by the vascular system in post-hemorrhagic states than of blood itself when this is used in transfusion. The total blood mass has even been tripled without seriously increasing the blood-pressure. Dastre and Loye (1888), in their early experiments, demonstrated that the equivalent of two-thirds of the body-weight of the animals experimented upon could be infused (saline solution) into the circulation without ill effects. Seven pints at one infusion was the greatest quantity used by Crile and Dolley.

On the other hand, the amount of fluid that can be infused with benefit is necessarily limited. Dastre and Loye demonstrated in 1889 that when isotonic saline solution was infused in quantities greater than the kidneys could eliminate that the fluid transuded out of the vessels and lodged in the serous spaces and large splanchnic cavities. Albu (1891) caused edema of the internal organs and general dropsy by infusing saline solution in supersaturating quantities. Hallion and Carrion (1900) and others have shown that one-third of the saline fluid infused finds its way out of the vessels and is eliminated by the kidneys, and what is not eliminated is stored up in the muscles, connective-tissue spaces, skin, and the visceral organs.

Therefore, the quantity of saline solution to be infused into the circulation must be regulated or determined by its effects. In the post-hemorrhagic collapse from acute anemia, 1 or 2 pints will often suffice to restore the radial pulse from a scarcely appreciable throb to its normal volume and frequency. The prognosis is graver with the increased quantity of the infusion required to restore the pulse. A pulse that is not improved by 4 or 5 pints will usually not improve with greater quantities. Direct blood transfusion may, however, bring about a favorable change when saline solution fails.

Animal experimentation and clinical experience have recently shown

that the more complex mineral solutions, such as Ringer's and Locke's fluid, the last especially, in which the chemic composition of the blood is more closely imitated, are more effective than the simple decinormal salt solution in preserving the vitality of the blood-vessels, as shown by the adrenalin reaction. They also act better in increasing the coagulability of the blood, as shown by Fleig. Locke's solution is also to be preferred in exhausted states.

In administering saline infusion intravenously or by other routes, stimulating remedies may be added to the solution. Adrenalin is especially indicated and should be administered by the method of Crile: "As soon as the solution begins to flow in the vessel, thrust the needle of a hypodermic syringe filled with adrenalin chlorid solution (1 : 1000) through the rubber tube near the cannula, and during about one minute inject 10 to 15 min.; digalen (Cloetta) may also be added to the solution in some cases (1 to 2 cm.), or the sterile preparations of ergot (ergone, ergotol, 1 to 2 drams of either), as these may advantageously reinforce the action of the adrenalin, which is fleeting, owing to its rapid oxidation in the blood. In administering saline infusion the flow may be interrupted occasionally as the pulse improves, the cannula being left in the vein while observing the condition of the circulation.

Great care should be exercised in avoiding too rapid filling of the vascular system for fear of dilating and paralyzing the right heart. It is best to begin gradually—2 to 3 c.c. per minute (Dastre and Loye, Crile); never faster than 1 liter in ten minutes (Dawbarn) or 1 liter in twenty minutes (Delbet-Veau). The condition of the peripheral veins should be watched all the while the injection is proceeding, as it is from the venous side that the first warning of impeded circulation from overdistention of the heart will be given. Crile's admonition on this point is of great importance: "In acute hemorrhage, when the heart muscle itself is functionally impaired by the diminished flow of blood through the coronary arteries, if the amount of fluid is suddenly increased by a rapidly increasing circulation, the heart's work is so rapidly augmented in the presence of weakness that it may suddenly suffer an acute dilatation and immediate paralysis ending in death may follow." Infusion is, therefore, contraindicated in all cases in which there is already a dilatation with distention of the right heart and consequent general venous stasis. This is recognized clinically by a turgidity of the superficial veins and a livid discoloration of the face and mucous membranes, lips, and extremities. "When the pulse shows a large wave, with but little resistance and a markedly slowed rhythm, great caution is necessary." If this occurs, stop the infusion immediately, prop the patient up on pillows or tilt the operating table so as to have the head up and the feet down. In this position blood will gravitate from the heart and large thoracic veins into the splanchnic area and into the large venous trunks of the lower extremities. In addition, rapid massage of the heart by rhythmic compression over the precordia and epigastrium, combined with artificial respiration, will relieve the cardiac embarrassment. After the cyanosis has subsided, infusion may be tentatively and very

gradually resumed. The tendency to acute dilatation and paralysis of the heart is much less frequent in hemorrhagic collapse than in shock, whether this be due to accident or sepsis.

Technic of Infusion.—As formerly employed, the radial artery was selected and the stream was directed toward the periphery (Hueter's method). Quite recently infusion has been attempted directly into the carotid, toward the heart, and against the current, with the object of reaching the coronary circle and thus stimulate the myocardium (Spina). Fluid injected in this manner toward the heart drives before it the column of blood contained in the arteries, so that the sigmoid aortic valves are closed and the blood is forced into the coronary vessels. As a result, the heart begins again to beat, and the animal is resuscitated. The *intra-arterial* injection of Locke's solution or artificial serum may be regarded as the most direct form of cardiac stimulation by the circulatory route. The method has yielded favorable results in laboratory animals, and Zesas thinks that it should be tried on the human subject.

FIG. 68.—NOZZLE TIED IN VEIN AT ELBOW. (Dorsett.)

Intravenous Infusion.—The method of infusion most commonly employed is the injection of hot saline solution into a superficial vein, or "intravenous infusion," the stream being directed toward the heart. Occasionally a vein in the operation wound may be used.

The technic of intravenous infusion applies to any superficial accessible vein. "The most prominent vein at the bend of the elbow is chosen. If the vein be prominently marked, incise directly over and parallel with it. If not marked, incise obliquely or transversely across the known course of the median basilic vein, the incision running parallel with the direction of the bicipital fascia. Proceed carefully until the vein is located. Expose from 2.5 to 4 cm. (1 to 1½ inches) of the vein. Pass two catgut ligatures beneath the vein, about 2.5 cm. (1 inch) apart, and tie the distal one permanently. With a pair of sharp-pointed scissors, curved on the flat, an oblique incision is made through one-half of the vein, between the two ligatures, the apex of the V pointing distally. Into this oblique opening into the vein, the cannula (after seeing that no air is in the instrument) is introduced, and the proximal ligature is tightened about it with a friction knot. Through this is allowed to flow,

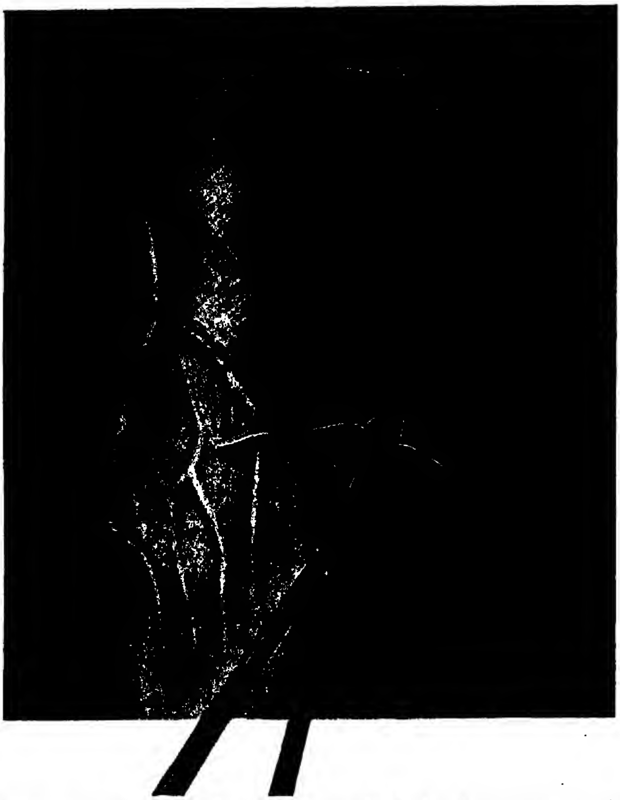
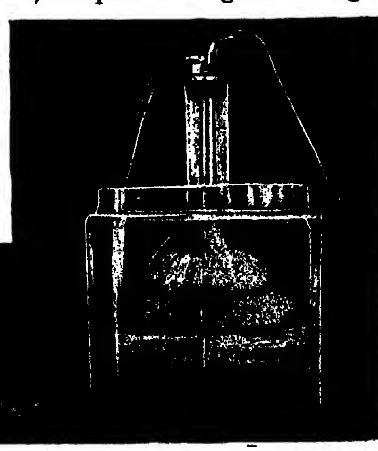


FIG. 69.—MODE OF SNIPPING VEIN TO ADMIT NOZZLE OF INFUSING TUBE. (Dorsett.)

by static pressure, as much fluid as is indicated (generally from 1 to 6 pints). The cannula is then withdrawn, the proximal ligature is tightened and tied permanently, and the vein is completely severed. The wound is sutured, or closed with adhesive strips, and the dressing applied" (Bickham).

Intravenous infusion finds its application: (1) In a very severe




A

FIG. 70.—INTRAVENOUS SALINE INFUSION. (Fowler.)

A, The lower ligature is tied and the upper ligature is in place ready for tying. The valve-shaped opening in the vein is shown ready to receive the cannula. *B*, Flask containing the saline solution. This flask is an ordinary wash-bottle, the long glass tube of which is connected to the infusion cannula and the short glass tube to a rubber bulb with valves. By pumping air into the flask above the solution the latter is forced into the veins.

acute anemia, after major operations, injuries, gastric and pulmonary hemorrhages, extensive hemorrhage during and after childbirth, placenta prævia, etc. (2) In great loss of fluid, as in Asiatic cholera. (3) For the flushing of the vascular system (Lavage du Sang), in acute poisoning, auto-intoxication, such as the typhoid state, diabetic coma, puerperal fever, eclampsia gravidarum, bubonic plague, uremia, blood-poisoning following venesection ("Saignée transfusion," Claisse). (4) For resuscitation in suspended animation (Locke's solution injected into the carotid artery, with reversal of the current). (5) In chronic postoperative anemia and for artificial nutrition (Locke's or Lennander's glucose saline solution or sterile isotonic sea-water ("Plasma de Quinton").

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Hypodermoclysis.—In addition to the intravascular route, saline infusion may be given *subcutaneously*, *intraperitoneally*, or *by the rectum*. (For Hypodermoclysis, see Vol. I., p. 942, Fig. 257.)

Intraperitoneal Infusion.—Infusion directly into the abdominal cavity, or intraperitoneal infusion, was first proposed by Ponfick, in 1879. In surgery this method is practised by pouring hot saline solution directly with the pitcher into the peritoneal cavity. The tendency at the present time, however, is toward using less irrigation of the peritoneal cavity, especially in septic cases, and also to depend more upon rectal infusion (Murphy) or hypodermoclysis.

Enteroclysis is more simple in its performance, neither assistance nor sterilization being necessary. The *rectal administration* of large quantities of salt solution has been generalized by the distinguished advocacy of J. B. Murphy, of Chicago, in the management of diffuse or general peritonitis. (Vol. III., p. 775, Fig. 386.)

Constitutional Treatment of Internal or Non-surgical Hemorrhages.—In the internal and strictly medical hemorrhages in which there is no access to the bleeding point and great uncertainty as to the

conditions by which hemostasis is to be effected, the fundamental principles of treatment should be to *aid natural hemostasis by all measures calculated to insure general rest and diminish functional activity of the bleeding part or organ; to diminish the blood-pressure and relax the circulation; to favor coagulation at the bleeding point.*

Dixon (London, 1906), in his able study of the so-called hemostatic effect of the vasoconstricting drugs, finds that adrenalin, digitalis, and its allies—ergot, veratrin, the tannins, barium, and lead—are all worse than useless for nearly all internal hemorrhages of the brain, lungs, and even the liver. "Upon what drugs, then, can the physician rely in these conditions? In dealing with internal hemorrhages, it is evident that it is of the utmost importance to prevent any stimulation of the heart or vasomotor constrictors, either of which may be produced very readily reflexly by any mental disturbance. The most efficient prophylactic is to diminish all sensory reflexes by means of morphin. Morphin has no action on the heart or vessels directly, but by inducing quietness, placidity, and desire for sleep, it prevents sudden movements, excitement, and other effects which induce cardiac acceleration and reflex rise of blood-pressure. . . . Experience abundantly confirms this view: witness the effect on patients suffering from hemoptysis and hemothorax, and from gunshot wound in the chest. After dismissing all drugs which increase the intravascular tension as dangerous and useless, we still have drugs which increase the coagulating power of the blood."

Calcium Chlorid.—Calcium is, *par excellence,* the drug for this purpose, and should be given subcutaneously. One or two grains administered in this way will diminish the time of blood coagulation of a healthy man to about one-half. For this purpose the calcium chlorid should be neutral and injected deeply into the tissues of the patient, with a maximum concentration of not more than 1 to 20 parts, so that, as far as possible, the local irritant action of the drug may be avoided (Dixon).[1] Plain saline solution or, preferably, Locke's solution injected intravenously, also favors coagulation, but in this way is much more valuable in preventing the recurrence of hemorrhage than in arresting it when it has started, as it increases the blood tension.

Gelatin.—The accelerating influence of intravenous injections of gelatin upon the coagulation of the blood was studied by Dastre and Floresco in 1896. They injected a 5 per cent. solution of gelatin into the tibial vein of a dog, and found the time of blood coagulation taken from the tibial artery considerably decreased. As a constitutional

[1] Formulæ (Gaz. des Hôpitaux, Paris, August 13, 1907):

℞. Calc. chlor., pure, 10 gm.; chloroform water and tinct. of orange-peel, of each, 30 c.c.; simple elixir (U. S. P.) or distilled water, 90 c.c., or

℞. Calc. chlor., pure, 10 gm.; peppermint syrup, 60 c.c.; distilled water, 90 c.c., or

℞. Calcium chlor., pure, 10 gm.; syrup bitter orange-peel and Kirschwasser, of each, 30 c.c., simple elixir, 40 c.c.; distilled water, 50 c.c.—Mix.

One-half ounce, or 15 c.c., of each one of the above mixtures contains 1 gm. (15 grains) of calcium chlorid. A standard solution of calcium chlorid, 10 gm., in distilled water, 300 c.c., may be kept on hand for ready use. Each tablespoonful (15 c.c.) of this solution contains ½ gram of calcium chlorid. This is best administered with milk, either by mouth or by enema.

hemostatic it is used in the form of sterilized gelatin (1 to 2 per cent.) dissolved in physiologic salt solution; 100 to 200 c.c., at a temperature of 37° C., are injected daily until some effect is observed. Carnot's solution, modified by Sailer, is to be preferred, as all possible risk of contamination with the tetanus bacillus is eliminated.

Carnot's solution, modified by Sailer: "Take 5 gm. of common salt, 1 liter of distilled water, 100 gm. of gelatin. Bring the water to 80° C., and slowly stir in the gelatin until it is all in solution. Remove the solution from the stove, cool it to 40° C., and add to it the white of an egg, stir for several minutes, and then put the flask on the stove and boil the fluid. The white of egg coagulates and clears the fluid. Filter through gauze and then through paper. Place the fluid in test-tubes, each of which will contain 10 c.c., and insert a cotton plug in the mouth of each tube. Sterilize by putting the tubes in a steam sterilizer fifteen minutes on two successive days. When you wish to use a tube, place it in a cup of hot water until the gelatin liquefies, pour the gelatin in a sterilized glass, and draw it up into a sterilized syringe. When kept several weeks the tubes dry out (DaCosta).

Stagnin, stypticin and *milk*, given by the rectum (1 to 2 pints mixed with a little salt), have all been used. The addition of calcium chlorid, 20 grains to 1 pint, increases the hemostatic action of milk.

Thyroid extract (internally) as a means of shortening the coagulation time of the blood, especially when surgical interference is required in hemophilic patients, has been recommended by W. J. Taylor.

Reconstructive Measures.—Finally, after the hemorrhage has been arrested and the effects of the mere quantitative loss of blood have been overcome, the *qualitative* or functional loss must be restored. For this purpose the essentials are a liberal dietary, including fresh meats and other proteids, fresh air and sunlight, rest, mental and physical, and the administration of some ferruginous preparation as an adjunct, according to the special needs of the patient.

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Local Hemostatics.—In addition to the preceding remedies, we find a group of *local remedies* which act topically, through their mechanical action, or as biologic (vascular) astringents to the tissues, or as chemical coagulants and caustics. The first group is well represented by Penghawar Djambi, the wooly hair of an East Indian fern

(cibotium cuminghi), which mats with the tissues after the wound has been lined with iodoform gauze and packed with the vegetable hemostatic. Like the gauze itself, Penghawar Djambi acts mechanically by absorbing the wound fluids and swelling up in the wound cavity.

Adrenalin.—The type of the biologic tissue astringents is adrenalin, which is employed in the solution of 1 : 1000 in the treatment of capillary bleeding from the mucous surfaces of the ear, nose, and throat in operations upon these regions. The local application of adrenalin is followed by a vascular contraction of the capillaries and arterioles, which is not invariably permanent, however, and may be replaced by hyperemia and vascular relaxation. It may be applied to the wound in form of a powder (5 to 10 gr. of the extract), but preferably as a compress or pack saturated with a 1 : 1000 adrenalin solution.

Gelatin.—The group of local coagulating agents includes chemically pure gelatin, which is used locally, dissolved in physiologic salt solution. A solution of 5 to 10 per cent. is heated to about 40° to 60° C., and applied to the bleeding wound by means of a gauze compress. The danger of tetanus infection should make the operator particularly careful to see that the gelatin is absolutely sterile. (See Seiler's Method.)

The general advantages of gelatin treatment consist in: (1) Its action in favoring coagulation; (2) its behavior toward the nutrition of the cells, assisting the organization of the thrombus; (3) its harmlessness provided the necessary precautions are adopted to secure its sterility; (4) the readiness with which it can be procured.

Chemic Styptics.—As a whole, the mechanic coagulants and caustic agents are unsurgical in the sense that they disturb, sometimes absolutely interfere with, the process of repair in the wound. This is especially true of the caustic styptics, of which the best-known preparations are the iron salts, all of which are to be absolutely proscribed in modern wound treatment. On the other hand, there are a number of agents which are not destructive to the tissues, and are at times of the greatest utility in controlling persistent parenchymatous hemorrhages in inaccessible cavities. Of this class, perhaps the most efficient is gelatin solution with adrenalin, combined in normal saline, used as a pack in oozing hemorrhages. Other conditions, especially bleeding ulcers in malignant neoplasms (*e. g.*, uterine cancer), are more effectively treated by packing them with sachets of less soluble local astringents and hemostatics, either alone or in combination, as, for instance, a mixture of tannin and antipyrin, equal parts (R. Park). Antipyrin combines the properties of a local hemostatic with those of an antiseptic agent. A gauze bandage wrung out of a 5 per cent. solution is advantageously employed to cover bleeding surfaces or to pack oozing cavities. In the nasal cavity it may be administered as a spray with an atomizer. Ferripyrin, a combination of antipyrin and iron chlorid, in 20 per cent. solution, is recommended as useful for the control of capillary bleeding epistaxis. A valuable local hemostatic is the well-known compound alum powder (Squibb's surgical powder), which is not only astringent, but antiseptic, on account of the

naphthol contained in it. A gauze sachet filled with this powder can be made to fit the size of the bleeding cavity, where it may be allowed to remain indefinitely. As it retains its antiseptic properties it neutralizes any putrefactive products which so often coexist with the ulcerations which cause the hemorrhages. The valuable hemostatic properties of oil of turpentine as a local application should not be overlooked in this connection.

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Direct Transfusion of Blood.—(See Chapter LXXII., p. 615.)

POSTOPERATIVE HEMORRHAGES.

Gastro-intestinal Hemorrhages.—Most important because of their frequency and grave prognostic significance are the postoperative hemorrhages of the gastro-intestinal tract, especially after abdominal operations, in which bleeding is manifested by hematemesis or hemorrhagic or melanotic stools. These hemorrhages may be grouped into two great classes: (1) Those due to *non-septic* and (2) those due to *septic* causes.

The *non-septic* cases include the postoperative hemorrhages which appear shortly or immediately after the operation. These early hemorrhages are due to traumatism of some kind or defect in technic (*e. g.*, when an unnoticed appendicular artery has not been sufficiently controlled by ligature, the stump being simply inverted into the cecum after applying a purse-string suture). These exceptional cases can be separated from another group in which the hemorrhages occur three or four days after the operation, thrombosis of the large vessels of the mesentery or omentum, secondary ulcers or erosions in the stomach or intestines playing a leading part. In this group the original traumatism incident to the operation is still largely responsible for the hemorrhagic complication. When these hemorrhages occur without demonstrable ulceration, the bleeding is ascribed to diapedesis of altered blood, preceded by stasis. Tiegel and Busse, however, express the need of caution before accepting this conclusion, in view of the ease with which minute, almost microscopic, erosions are overlooked. Up to the present time it has never been positively proved that in these postoperative hemorrhages the blood was venous or arterial (Summers). The pathogeny of these intestinal hemorrhages was first elucidated by Litten's classic experiments in 1875; Schnitzler, Ullman, Kukula, and Sauvé have completed the demonstration of the relationship of mesenteric infarcts with these hemorrhages. Summers and McCrae have aided in diffusing this knowledge in America.

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Hemorrhages Caused by Infectious Processes.—Notwithstanding the recognition of traumatism as the primary factor in the causation of postoperative hemorrhages, the differentiation between the *non-septic* and the *septic* is most important from the prognostic point of view. While traumatism *per se* will give rise to postoperative hemorrhages, the dangers of endoangeitis (Welch), with consecutive hemorrhage, are enormously increased by the addition of the complicating influence of sepsis. This tendency to hemorrhage is especially pronounced in the great colonic, staphylo- and strepto-coccal infections. Hematemesis and melanotic or bloody stools occur as independent manifestations of general septicemia and toxemia following septic or purulent peritonitis. These hemorrhages are most likely to occur after operations on the gastro-intestinal tract for strangulated hernias, radical cure of hernia, etc., in which the omentum is resected, ligated, etc. Busse showed by experiments that hematemesis could be produced in the lower animals by torsion of the omentum. Gastrorrhagia and intestinal hemorrhages are likely to occur with greater frequency in operations on the stomach, duodenum, biliary tract, liver, pancreas, and after renal operations. They occur with less frequency after operations on the pelvic organs, thus confirming the view generally held by pathologists that their causation is largely related to obstructive disorders in the portal radicles and in the mesenteric arteries. In appendicitis "black vomit," "coffee-ground vomit," from capillary oozing into the stomach, with fever, jaundice, urobilinuria, albuminuria, oliguria, and anuria, is not an infrequent occurrence in the virulent septic cases. Bloody vomit has been observed as an ephemeral symptom in 16 out of 156 septic cases of acute appendicitis (Fernau); 4 in 1000 cases of all kinds at Johns Hopkins Hospital, which is an extraordinarily low percentage, I myself having observed it in at least 10 per cent. of the grave septic and neglected cases of former years. The bloody vomit may appear from eight to thirty-six hours after operation, and on the fourth and fifth days, as observed by myself. Busse records 16 cases of gastro-intestinal hemorrhage in a collection of 96 cases in which this symptom occurred as a postoperative complication.

Considering the frequency of pyelophlebitis after appendicitis, the absence of massive gangrene of the bowel consequent upon extensive mesenteric infarction or obstruction is remarkable.

The tendency to continued, uncontrollable, *postoperative bleeding* from the wounds of subjects suffering from chronic obstructive jaundice in which profound histologic changes in the liver are in progress is one of the most formidable obstacles to success in the surgery of advanced hepatic disease; and its importance to the surgeon cannot be overestimated. A general hemophilic tendency is characteristic of chronic jaundice, especially the so-called "black jaundice." Hemorrhages into the skin are common, while epistaxis is frequently the cause of great anxiety. Frequent oozing from the gums occurs. The coagulation time of the blood in chronic jaundice shows a marked retardation. Instead of coagulating in four minutes it may take fifteen or twenty minutes or longer (Osler). The most likely explanation of this phenomenon is that the damaged liver fails to stop poisons and bodies allied to peptone (thrombase), absorbed from the alimentary canal, and are allowed to enter the circulation as anticoagulant bodies (Lezenne, Doyon). It has, however, been suggested by Mayo Robson that the hemorrhagic tendency is pancreatic in origin. In the treatment of this form of obstinate hemorrhage the prophylactic administration of calcium chlorid by mouth or enema appears to be the only measure which has thus far proved beneficial. The use of blood-serum to furnish deficient ferment bodies, as suggested by Weil, in hemophilia is also advisable.

Treatment of Postoperative Hemorrhage.—This is based upon the ability to deal with the primary source of hemorrhage by a direct effort to control the bleeding point. In the vast majority of non-septic gastro-intestinal hemorrhages very little treatment is required, as the patients usually proceed to recovery; though they may be left with permanent lesions (which is very exceptional) in the gastro-intestinal tract from ulceration. Kehr recommends that, in addition to the subcutaneous infusion of normal salt solution and rectal alimentation, the stomach should be washed out with 1 per cent. solution of nitrate of silver, followed by further washing with plain cold water. In addition, ergot is administered subcutaneously. Summers suggests continuous irrigations with hot water through a stomach-tube or through a surgical fistula into the stomach directly; and in very weak patients the stomach-tube, with hot or iced water, medicated or not, in conjunction with intravenous or subcutaneous saline infusion, to which calcium chlorid and gelatin should be added. When the blood has been traced to a fresh gastric ulcer in a late postoperative case, radical surgical treatment would consist in gastrotomy and obliteration of the bleeding area by a purse-string suture applied from within, which is further protected by sutures introduced from without after the gastrotomy wound has been closed.

In the septic cases every effort must be made to purify the primary focus of the infection by drainage, or by the removal of the appendix with its mesentery, as Gerster recommends, in cases in which mesenteric infections are attributable to a primary thrombophlebitis of the appendix and its mesenteriolum. Usually, however, nothing can be done by local measures, as the infection has gained the circulation and

is beyond the reach of local treatment. The various modes of treatment of the constitutional infection (bacteremia, septicemia) offer little encouragement, whether in the form of antitoxic sera or artificial hyperleukocytosis (Mikulicz), or by the use of other agents introduced into the circulation, which are more fully discussed under the heading of Purulent Phlebitis and Septicemia. It is possible that the further application of Wright's and Douglass' vaccines may give us more encouragement in this direction.

The prognosis of septic postoperative gastric and intestinal hemorrhage is extremely grave. Hematemesis, as one of the symptoms of pyelophlebitis, has an absolutely unfavorable prognosis. In sepsis secondary to peritonitis, the prognostic significance of hematemesis is very bad, since it occurs in very severe cases only. Hematemesis accompanying peritonitis after operations in the abdominal cavity is of very serious augury, and is almost invariably indicative of sepsis. Surgical intervention is called for in exceptional cases only. As a rule, treatment must be merely symptomatic. Stimulants are indicated, and the employment of saline infusion may act as a life-saving procedure. In the presence of complications of a thrombotic or embolic character the treatment is necessarily conservative and expectant, with the exception of hepatic and pulmonary abscess, which require incision and free drainage. Thrombotic obstruction of the mesenteric vessels, which causes hematemesis and intestinal hemorrhages in connection with intestinal necrosis, is only amenable to surgical treatment, and even then offers the gloomiest prognosis, as will be seen by referring to the section on Mesenteric Thrombosis.

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THE HEMORRHAGIC DISEASES AND THEIR TREATMENT.

The coagulability of the blood is lessened and the persistence of hemorrhage favored by certain changes in the constitution of the blood, the exact character of which is still a subject of investigation. These constitutional anomalies are met with specially in hemophilia,

purpura, scurvy, Barlow's disease, leukemia, and prolonged icterus, especially when this is due to malignant disease. Patients suffering from any of these diseases are accordingly unfavorable subjects for any form of surgical interference. The abnormal tendency to hemorrhages, characteristic of the hemorrhagic diathesis, is distinguished by the spontaneous occurrence of the hemorrhages, by their great severity and their long duration, together with the slightness of the causes that provoke them. A true hemorrhagic disease is usually an infection in which a variable clinical picture is dominated by a common symptom, namely, the persistent tendency to bleed.

Hemophilia.—The hemophilic diathesis, or tendency to bleed at the slightest provocation, or even spontaneously, exhibited by certain individuals otherwise healthy, is known as hemophilia.

The hemophilic diathesis may manifest itself at all ages, but in its most typical form is characteristic of early life and especially of the first two decades. Sex plays a very notable part in the history of this disease, males being infinitely more subject to it than females. Hereditary transmission is an undisputed and most conspicuous characteristic of this diathesis—and what is more curious is that it is always conveyed from one generation to the other, through the mother, even though she herself be exempt from hemophilic manifestations. On the other hand, the male of hemophilic stock cannot transmit the disease to his children, unless he himself be a victim of the disease. This general law laid down by Grandidier is not absolute, and has been contradicted by later statistics of Kolster, Retterschorn, and de Bovis, which show that hemophilia manifests itself with almost equal frequency in the infancy of both sexes. The hereditary or family tendency to hemophilia may skip one or more generations and then unexpectedly appear as an atavistic trait after a long interval of latency. There is also a *sporadic*, *accidental*, or *acquired* hemophilia, which it is very important to recognize on account of its prognostic bearings. The difference between the acquired and the hereditary types have been especially brought out by Weil.

Pathogeny.—The essential factor in the causation of hemophilia still remains problematic, notwithstanding the time and immense labor devoted to its elucidation since the days of Fordyce (1784). The progress of histology and hematology has ruined all the old theories by showing the absence of structural abnormalities in the vessels or of any notable alterations in the blood.

Sahli, who in 1905 investigated this question with all modern resources, failed to arrive at a solution of the problem. He found no appreciable abnormalities in the morphology of the blood, in its osmotic tendencies or alkalinity, or in the blood-pressure. He concluded that the coagulation of the blood is at fault, and that the cause lies chiefly in the endothelium of the vessel-wall. A very elaborate and suggestive theory of the causation of hemophilia based upon Ehrlich's researches on immunity has been recently presented by Wachenheim, of New York. As an abridged statement of this thoughtful author's view would con-

vey no intelligent explanation, the reader is referred to the original text.

As recently shown by Emil Weil, hemophilia presents itself clinically in two distinct forms: the accidental or acquired hemophilia and the hereditary or family type. Clinically, the acquired "sporadic" type is distinguished from the hereditary by its relative benignity—*i. e.*, it does not cause such frequent or great hemorrhagic manifestations. In the accidental variety a traumatism of some importance is necessary to bring about a hemorrhage of any serious consequence. The hemorrhages in this type are also separated by long intervals of time, sometimes years. On the contrary, the tendency to obstinate bleeding in the congenital variety is manifested from the moment of birth; the slightest prick, wound, or blow may provoke interminable hemorrhages. Sometimes the hemorrhages appear to come spontaneously, so inappreciable is the provocation. The hemorrhages into the joints—hemarthroses—are distinctive, if not exclusive, manifestations of the congenital type, and occur not only after the slightest injury, but after mere muscular effort or fatigue. The mortality is very considerable in hemophilic families and death is frequent at a tender age. In his recent and interesting research Weil has shown that blood can be obtained directly from the superficial veins of hemophilic subjects without danger by using a fine hollow needle. After puncture through the skin the blood flows as long as it may be needed. No hemorrhage follows the removal of the needle, the elasticity of the veins being sufficient to occlude the puncture and secure complete hemostasis.

The dominant characteristic of hemophilic blood is the extreme retardation of coagulation. If allowed to drop from a vein into a test-tube, the corpuscles soon drop to the bottom, the coagulum forming only after the lapse of from *one* to *nine* hours. Distinct differences separate the blood of the accidental and hereditary types of hemophilia. In *accidental* hemophilia the blood is very fluid, the flow from a needle introduced into a vein is rapid and prolonged; the corpuscular field is normal in appearance, the leukocyte count is also normal or subnormal, the coagulation is "plasmatic," but the time is long delayed—seventy-five minutes on the average; the clot when formed is solid and the serum abundant. In the *hereditary* type the blood is sticky, viscous; the flow from the needle is slow and less persistent; the blood-picture is normal in appearance, except that leukopenia is constant and there is an excess of mononuclear leukocytes; the time of coagulation is enormously retarded (two and one-quarter to nine hours). The clot is white, soft, flocculent, with less serum. These marked differences between these two types of hemophilia, as clearly shown by Weil, are not only important in determining the relative prognosis of the disease, but are of special value in guiding the practitioner in the application of serum therapy as devised by this investigator.

The **symptoms** of hemophilia are extremely variable. The hemorrhages are practically always capillary, the blood escaping as in parenchymatous bleeding, *i. e.*, slowly exuding without spurting. Hemorrhage from the large arteries takes the customary course, and can be

controlled by ligature. The duration of hemophilic hemorrhage is variable. Not extraordinarily profuse at a given time, it assumes dangerous proportions by the enormous amounts of blood which are gradually lost in a hemorrhage extending over a period of weeks and months. In the statistics of the fatal cases of hemophilia collected by Grandidier, the trivial character of the injuries which led to death is shown by the following: there were 14 deaths from cracks or fissures about the skin and lips; 11 from superficial wounds of the scalp; 7 from accidental wounds of the tongue caught between jagged teeth; in 42 fatal cases (Grandidier) death occurred 10 times after tooth extraction; 8 after blood-letting; 4 after leech-bites; 4 after wet-cups; and 4 followed circumcisions.

The *articular* swelling and pains in the limbs, occurring in hemophilics, and formally interpreted as rheumatic, are now referred to hemorrhages into and around the joint capsule. These articular effusions tend to become more prominent after the period of puberty, before which the hemorrhagic phenomena predominate. The knee is the favorite seat of a hemophilic arthropathy. A simultaneous or successive involvement of several joints is sometimes observed, but it is the knee which is first attacked. The clinical history of the hemophilic joint is divided into three periods by Koenig, whose masterly study of this articular affection has remained a classic since 1891: (1) Period of articular effusion or hemarthrosis; (2) period of chronic arthritis; (3) period of ankylosis and permanent deformities.

The first period is essentially characterized by an extravasation of blood in the joints, usually an acute hemarthrosis; the knee becomes globular in shape, tense, painful on hard pressure, and fluctuating. The skeleton of the articulation is not tender or sensitive, and the function of the joint is limited solely because of the disturbing effect of the effusion. There are no local inflammatory signs; there is sometimes a slight elevation of temperature. The duration of this hemarthrosis is generally short; in a few days the blood is absorbed, and in eight to fifteen days the joint is restored to its normal function.

Unfortunately, frequent relapse is a characteristic of this affection. As many as forty recurrences in the same patient have been reported by one observer (Gocht). The constant repetition of these hemorrhages brings about a second or arthritic stage, which is characterized by chronic inflammatory changes in the synovial sac and roughening of the cartilages of the joints. The comparative lack of pain, however, permits the patient to use the joint in walking until an acute exacerbation compels a halt. At this stage the dystrophies of the particular muscles become marked, giving the joint the spindle-shaped appearance of a white swelling. The synovial sac thickens, enlarges, and hardens; adhesions form, and ankylosis, the third stage, develops, which cripples and deforms the joint.

In the *treatment of hemophilic joints* the essential is to avoid all operative procedures. Even exploratory puncture should be avoided, if possible, but an exploratory puncture with an aspirating needle to

reveal the hemorrhagic nature of the effusion is infinitely less serious than arthrotomy or arthrectomy, which will invariably lead to disaster. The only treatment, in view of the prompt absorption of the hemorrhagic effusion in the first stage, is rest with immobilization and gentle compression, avoiding massage (Broca) for fear of extravasations. In the arthritic and deforming stage, a vicious attitude must be avoided by gentle extension, never by violent manipulations or attempts to break adhesions. Possibly, as Delbet and Schwartz suggest, it may be that in the future, by a judicious use of normal serum by the method of Weil, or the use of thyroid extract as recently applied by Torrance Rugh, of Philadelphia, it may be possible to control the hemorrhagic tendency sufficiently to permit of the correction of the deformity with comparative safety in the advanced cases. The differential diagnosis in tuberculous arthritis will be materially assisted by the history of the patient; by *x*-ray examinations; by the cuticular reaction of von Pirquet, or the Wolf-Calmette ophthalmic test.

Hemophilia may end in recovery, a more likely termination in the mild, benign, or accidental cases—so-called "abortive hemophilia." In the typical hereditary cases the prognosis is gloomy indeed. The oft-quoted statistics of Litten show that 60 per cent. of hemophilic subjects die before the eighth year and only 11 per cent. survive after the twentieth. After the first two decades of life the prognosis improves steadily with advancing age.

Treatment of Hemophilia.—The therapeutics of hemophilia are as unsatisfactory as its etiology. There is no specific remedy that will deal with the condition etiologically. While the use of special food-stuffs (vegetables) is of no value, a general improvement of the nutrition of hemophilic patients is a great desideratum; meaning by this nutrition in its widest sense, inclusive of an abundant and varied diet, a suitable combination of rest and exercise, of sleep and waking; sometimes employing medicinal agents to meet special symptomatic indications. From the surgical point of view it is especially important that his condition be explained to the patient or his friends, who should be provided with a number of prophylactic measures no less than with explicit directions for emergency procedures.

In the control of hemorrhage in wounds and bleeding surfaces, the most reliable are *compression gelatin bandages* and compresses soaked in fresh normal blood-serum (Weil). For this purpose a bandage is soaked in sterilized gelatin (2 per cent.) and applied to the bleeding parts under pressure. For purposes of preservation, glycerin and chlorid of calcium may be added to the gelatin. This mixture is chiefly applicable to surface hemorrhages from accessible vessels or multiple bloody extravasations and in operations on bone. For local application, either gelatin, which solidifies at ordinary room temperature, or sterilized gelatin, which is rich in gelatose and becomes fluid at this temperature, may be employed, since the effect is essentially of a physical character. The subcutaneous injection of gelatin for the control of hemophilic hemorrhages by the general effect of the remedy,

has its opponents as well as its advocates, not only on account of the attendant danger from tetanus, but also because the supposed hemostatic effect is by no means universally credited. The internal administration of gelatin does not seem to be based on rational premises, since the gelatin does not reach the blood as gelatin at all (Sahli).

Adrenalin may be used as a local hemostatic, but is inert as an internal remedy. Its subcutaneous use is likewise rejected not only as unphysiologic on account of the resulting increase of blood-pressure, but because it is inert except by intravenous injection.

Calcium.—While too much should not be expected from the internal administration of lime-salts in hemophilia, the local application of calcium chlorid at the bleeding part is worthy of a trial, in form of a cotton pledget soaked in a 1 to 2 per cent. solution and firmly held in place. The lactate of calcium, in doses of 30 to 40 grains, once or twice in chronic cases, has recently been recommended. There is a case on record in which the internal use of ovarian extract proved successful after all other remedies, including adrenalin, had failed (Grant).

Thyroid Extract.—The recovery of a patient with a bad hemophilic joint (Rugh) suggests its further use in similar conditions.

Atmokausis has sometimes proved the last life-saving resort in hemophilic hemorrhages from the uterus (Pincus and Stoeckel). The bleeding has been observed to subside at once, after two or three minutes' use of atmokausis at 115° C. The method constitutes, according to Pincus, a specific against uterine hemorrhages of whatever origin.

Serotherapy.—A most valuable suggestion which has resulted from Weil's studies in hemophilia is that fresh animal or human serum when injected into hemophilic subjects greatly increases the coagulability of the blood. In accidental or acquired hemophilia it brings up the standard of coagulation to normal twenty-four hours after it has been injected, and this improvement continues for an average period of a month, when the treatment has to be renewed to prevent relapse. In the congenital type, blood-serum injections are not so effective. They markedly improve the clotting, but have little influence in shortentng the coagulation period. This is due apparently to the presence of anticoagulant bodies in the blood. Weil recommends the local as well as systemic application of the serum in bleeding wounds. To arrest hemorrhage in adults he injects 10 to 20 c.c. into the veins or 20 to 30 c.c. subcutaneously, the dose to be repeated if necessary on the second day. In children, half the dose is recommended. As a preoperative prophylactic the same dosage is indicated. The serum as obtained by venesection from man, rabbits, and the horse has been utilized, but normal human serum is undoubtedly most effective for man. Beef-serum must *never* be used, as it is always followed by severe toxic phenomena. In emergencies it is often impossible to wait twenty-four hours to obtain the fresh blood-serum of a rabbit, and a fresh sample of antidiphtheritic serum, which is always at hand, can be used with advantage in the same manner. Most cases thus far reported have been treated with antidiphtheritic serum, and, in the majority, with remarkably good

results. When fresh normal sterile serum can be obtained, it is to be preferred to the therapeutic antitoxic sera, as it contains all the desirable fibrin ferments and nothing more. This mode of treatment, while not at all specific in its character, is based on a rational principle, and has yielded sufficiently encouraging results since its introduction to deserve further trial, not only in hemophilia, but in all the allied hemorrhagic states.

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Aneurism.

Aneurisma (*ἀνεύρυσμα*, from *ἀνευρύνω*, to widen, dilate). In its fundamental meaning, the word aneurism is applied to a hollow tumor, space, or sac, filled with liquid or coagulated blood, or both, directly connected with the lumen of an artery (with which it is continuous), and developed in whole or in part at the expense of its walls. The essential ideas that are inseparable from the concept of an aneurism are: (1) That the interior of the sac must be directly continuous with the lumen of an artery; and (2) that the sac containing the blood must be well defined or encysted. *Arterial* aneurisms are anatomically divided into two distinct types: the true and the false. The *true*—aneurisma verum—are all those in which one or all the tunics of an artery enter into the composition of the sac; the *false*—aneurisma spurium—those in which the sac is formed entirely by adventitious walls, *i. e.*, by newly formed perivascular connective tissue, in which organized clots participate in the wall-building process. The aneurisma verum of the classic writers, in which the sac preserves the original three coats of the parent artery, is extremely rare, the middle coat (media) disappearing in all well-developed aneurisms. To avoid confusion, these arterial dilatations should be referred to as arteriectases, and represent the incipient stages of the cylindric and fusiform aneurisms

of the aorta or its primary branches. Sometimes the three coats are recognizable in the small miliary aneurisms of the cerebral or visceral arteries.

Classification.—According to their causation or their pathogeny, aneurisms may be classified into at least five groups (Thoma's classification modified): (1) Congenital aneurisms; (2) pathologic (the so-called spontaneous, idiopathic, but more properly arteriosclerotic aneurisms); (3) traumatic; (4) embolic; (5) erosion; (6) cirsoid aneurisms.

(1) *Congenital aneurisms* are almost pathologic curiosities, they are so rare. They appear occasionally as prenatal dilatations of the fetal vessels, especially the ductus arteriosus, which continues patulous and develops after birth. Rokitansky, Kussmaul, Mayer, and others have described congenital aneurisms which Eppinger attributes to a congenital histologic anomaly of the vessels—a dystrophy of the media—which impairs the elasticity and resistance of the vessel coats to the normal blood-pressure. In this way a congenital aneurismal diathesis may obtain in certain individuals which must be distinguished from the less rare and acquired diathesis of adult life, the result of a generalized disease of the arteries.

(2) *Pathologic* or *arteriosclerotic aneurisms* constitute a great majority of the aneurisms, especially those of the aorta and the internal arteries, met in practice. Under this heading are grouped all those aneurisms which are formed without apparent cause, hence "idiopathic" or "spontaneous," and in which there is no distinct history of direct injury to the artery. In these, one or more coats of the artery enter into the composition of the sac. They may be subdivided into two groups: (*a*) Those in which the aneurismal pouch is formed by a process of *dilatation* or stretching of the walls, the diseased, softened, and inelastic tunics yielding progressively to the expansile force of the blood-current; (*b*) by *rupture* or the giving way (atheromatous degeneration and ulceration) of the internal and middle coats at the diseased spots. This is the most frequent way in which an aneurism is formed. The elastic fibers of the intima and media, softened by atheroma, break down, the middle coat gives way, and the external coat, unable to resist the blood-pressure, bulges out, forming the sac of the aneurism.

By this process *dissecting aneurisms* are formed. An intramural channel is started in the thickness of the arterial wall, which admits the blood-stream and allows it to burrow its way for a greater or less distance along the lines of cleavage in the vessel until it finds an exit at a distance from its starting-point. A single artery is thus transformed into a double one for a very considerable distance. Dissecting aneurisms are almost exclusively met in the thick walls of the thoracic and abdominal aorta, in which the fibrous adventitia is especially strong. They have been occasionally observed in the sclerotic cerebral arteries. The interval separating the two internal openings of a dissecting aneurism may be 1 or 2 inches apart, or, as in some reported cases, the new tunnel may extend from the origin of the aorta to its abdominal

bifurcation. An interesting feature of these aneurisms is that when the intramural circulation has been established, the new channel becomes completely and perfectly lined with endothelium of new formation, which is in every respect identical with that of the normal artery.

When a mass of broken-down atheroma, consisting of semifluid, fatty, or chalky débris (steatoma of the aorta), breaks through the intima into the aortic lumen, and leaves a hollow or a cavity which serves as a recess for the formation of an aneurism, such aneurisms are known as *kystogenic* aneurisms; when they form shallow excavations with slight external bulgings they are known as the *cupoliform* aneurisms.

More often, after the break-down of the intima and media, a progressively increasing *sacciform* aneurism is formed, which communicates with the lumen of the artery by a relatively narrow orifice. These sacciform aneurisms, formed by the rupture of the two inner coats, are by far the most frequent of the aortic aneurisms (fully two-thirds). When such aneurisms press upon surrounding large veins (vena cava or pulmonary artery) they form pathologic anastomoses or fistulæ, arteriovenous aneurisms resulting from pressure atrophy.

(3) *Traumatic aneurisms* are those which are clearly traceable to injury of the arterial walls, by contusions, falls, gun-shots, stabs, punctures, and other penetrating wounds. In these, aneurism is the result of an injury done to a healthy or normal artery. More often, traumatism or injury only determines the localization of an aneurism in arteries already diseased. Much confusion has been caused in nomenclature by the misapplication of the word aneurism to the recent ill-defined collections of extravasated blood which follow certain contused and perforating arterial wounds. These hemorrhagic extravasations have no well-defined or differentiated sacs—an essential feature of an aneurism—and they should be distinguished by the term "pulsating hematomata," long ago proposed by Delbet, Michaux, and Rotter. These hematomata may be diffused into the tissues or circumscribed, but cannot be recognized as aneurisms until a well-differentiated wall is formed by the organization of the perivascular tissue and clot into a distinct fibrous wall, lined by endothelium of new formation. When a pathologic aneurism ruptures through all its coats, it may cause a secondary diffuse or circumscribed false aneurism—also called a *consecutive* aneurism. These arteriovenous aneurisms, as observed in the extremities, are almost exclusively of traumatic origin (*vide infra*).

(4) *Embolic aneurisms* may present themselves in three forms: (1) the simple or non-infectious; (2) the infectious, septic, or pyogenic; (3) the parasitic. The simple or non-infectious are caused by the lodgement of a migrated clot or a fragment of calcic atheroma in a vessel too small to allow its farther transit; a secondary traumatic endarteritis is produced thereby, ending in the yielding of the artery at the obstructed point. The septic emboli are always given off from pyemic foci in general infections; more often from the roughened surfaces of the

valves in septic endocarditis. Wherever they become impacted, these emboli infect the artery, causing a septic or pyogenic endarteritis, followed by infiltration, softening, and dilatation of the walls (the embolic mycotic aneurisms of Eppinger). (See Diseases of Arteries.) The parasitic or verminous aneurisms are found almost exclusively in the horse.

(5) *Erosion aneurisms* of Eppinger are small circumscribed aneurisms formed in suppurating cavities, in tuberculous vomicæ in the lungs, with rupture, causing profuse and often fatal hemoptysis. They are caused by infiltration of the adventitia by specific pathogenic micro-organisms, such as the tubercle bacillus, but more often by pyogenic micro-organisms, which erode and ulcerate the two outer coats; the weakened media, yielding to the intravascular pressure, bulges through the eroded area as a hernial projection, finally rupturing before attaining great size, causing the erosion hemorrhages already referred to.

(6) *Cirsoid aneurisms*, or aneurisms by anastomosis. Arterial varices or simple dilatations of the arteries (arteriectases), either singly or in plexiform masses, have been erroneously included in this group. These arterial varices differ essentially from cirsoid aneurism in two ways: (1) That veins of new formation participate in the process; (2) that the blood-vessels entering into the formation of cirsoid aneurisms are largely neoplastic, and are frequently reproduced *in loco* after apparently complete extirpation. Therefore, cirsoid aneurisms, so called, are not, strictly speaking, aneurisms—*i. e.*, a disease acquired or grafted on a preëxisting normal artery—but neoplasms or tumors with close affinities to the angeiomata.

Structure of Aneurism.—An aneurism consists of a sac and contents, and, in sacciform aneurisms, also of a neck. In considering the structure of the sac we must distinguish between—(1) the true aneurism, always associated with preëxisting arterial disease; and (2) the false, always of traumatic origin.

The true aneurisms may consist, as previously outlined, of: (1) All the coats of the artery, a very rare occurrence except in arterial ectases or incipient aneurisms; (2) the external coat only, as seen in sacculated aneurisms of pathologic origin; (3) the internal coat (erosion aneurism); (4) the separated layers of the middle coat, between which the blood has been forced with the external and internal coats on either side (dissecting aneurisms). *The one unfailing histologic characteristic of the structure of all aneurisms is that the middle or musculo-elastic coat is always missing in the sac-walls; and that the media never enters into the formation of the aneurism.* If the walls of an ordinary so-called spontaneous aneurism of considerable size and of the saccular type are examined, it will be found to be composed of a fibrous layer, the relic of the adventitia or of this membrane blended with condensed sclerotic connective tissue, lined on its inner surface by a thin membrane analogous to the intima of the parent artery. This internal lining presents a smooth endothelial surface of flat nucleated cells, resting upon a connective-tissue bed. These endothelial cells are formed by the proliferation of the intima of the parent artery. They multiply

with great rapidity and soon cover all the surfaces which come in contact with the blood-stream. Traces of the middle coat may be found scattered here and there in the sac, but even these soon disappear, leaving only a distinct layer at the junction of the sac with the normal arterial wall, where they are continuous with the elastic and muscular fibers of the media. These elements show no tendency to regenerate or form again once they have been destroyed and transformed into degenerative products by the arteriosclerotic and atheromatous processes. The newly formed endothelial lining and connective-tissue walls of the aneurism may itself undergo degenerative changes; fatty and calcareous transformation (atheroma). Sometimes the sac becomes so infiltrated with salts that it will crackle and break like an egg-shell under the pressure of the hand. It is a fairly constant law in arterial pathology that wherever the circulation is active, the tissues that are in contact with the blood-stream soon become lined with smooth endothelial cells, which spread by multiplication from the intima of the main vessels, and probably also from angeioblasts furnished by the vasa vasorum. Therefore, when a rupture of the distended coats of an aneurism takes place, the peri-aneurismal tissues with which the extravasated blood comes in contact soon become lined with newly formed endothelium, in imitation of the parent lining of the main vessel, provided the blood be in motion.

The practical point to be borne in mind is that it is only while the aneurism is still small and young that a distinction can be made between its coats. As the aneurism increases in size, the tissues around it become condensed and fused with the sac, which may ultimately be formed entirely of these tissues and of new fibrous tissue produced by chronic irritative hyperplasia.

The walls of the sac are of variable thickness, dependent upon a multitude of causes. In a general way it may be said of sacciform aneurisms that the walls become progressively thinner from the point of attachment or neck to the periphery or greatest bulge of the sac. In the typical fusiform type the sac is thinnest at its equator and thickest at the poles, where the vessel fuses with the sac, but as the fusiform outline is far from constant, it may be better to state that the sac-walls grow thinner, as in sacciform aneurisms, from the points of arterial attachment to the most distended portions of the sac.

The Structure of the Sac in False Aneurisms (Aneurysma Spurium).—These are always traumatic. In exceptional cases these aneurisms appear as cylindric or fusiform sacs. This occurs only when the artery has been transversely divided, the two ends retracting and the extravasated blood diffusing itself in the space between them. Instead of a direct junction of the divided ends, the communication is established by the interposition of an adventitious connective-tissue sac. As a rule, a traumatic arterial aneurism is the result of parietal injury, either in the shape of an open vascular wound due to a puncturing injury, stab, gunshot, etc., or of contusion of the vascular walls through the intact external skin. The wall under these circumstances is either

ruptured or injured so severely that it undergoes secondary degeneration. Given a large vessel with a lateral wound and an injury of the skin, the result may be a severe hemorrhage. In subcutaneous injuries the extravasated blood may diffuse itself widely throughout the tissues, causing a diffuse hematoma, sometimes so extensive and excessive as to cause death from vascular depletion. More often, however, the bleeding is arrested by the resistance and tension of the perivascular tissues, which confine the blood to a limited space, forming a circumscribed pulsating hematoma. This space is soon walled off by connective-tissue formation, consisting at first of granulation tissue, which matures into a dense connective-tissue layer, lined by newly formed endothelium. In this way a distinct capsule or sac is formed, which in time is highly differentiated from the surrounding tissues. This is the classic concept of the adventitious sac as it is formed in the spurious or traumatic aneurisms. On the other hand, when an artery is contused or sustains a parietal injury only, when the eschar forms in the case of a contusion, or when the hemorrhage occurs at the time of perforation, the opening in the artery is provisionally closed by a blood-plate-fibrin thrombus. The parietal thrombus soon yields to the blood-pressure, it stretches and is thinned out, adopting the form of a sac as it is forced against the perivascular tissues by the expansile force of the blood-stream. This mode of thrombotic saccular formation in traumatic aneurism was first revealed by the researches of Rose and his assistant, Hain.

Arteriovenous Aneurisms.—These are sufficiently important to deserve separate consideration. (See p. 290.)

Form (Morphology of the Sac).—According to the form, aneurisms are classified into—(1) cylindric; (2) fusiform; (3) sacciform.

The fusiform or spindle-shaped aneurisms are found most frequently in the great arteries at the root of the heart, the aortic arch, the thoracic and abdominal aorta, innominate, subclavian, common carotid, and common iliacs. They are most frequent in these localities because of the great thickness of their coats, forming a good nidus for infections, either through the intima or through the vasa vasorum, because the anatomic configuration and position as well as proximity to the heart subject them to greater strain in consequence of the great volume of the blood-stream. They also receive less support from the perivascular tissues than the arteries of the extremities, which are protected by powerful aponeurotic sheaths as well as masses of perivascular muscular and tendinous structures. While the aneurismal process is essentially initiated by diseased conditions of the arterial coats, there is usually an element of indirect traumatism brought about by variations in the arterial tension which favor the localization and development of aneurismal dilatation. While the fusiform type of aneurism is apparently restricted to the arteries of the first magnitude, according to classic tradition, it is also present and perhaps more often than the sacciform in the extremities.

The sacculated, saccular, or sacciform aneurisms receive their names

from their pouch-like appearance, as the name suggests. They form at the expense of the walls of the artery in a limited area of its periphery, leaving the outline of this part of the vessel well defined and uninterrupted, forming a collar or neck at the point where they are connected. We may, therefore, speak of sacculated sacs as pedunculated aneurisms in which the attached portion represents a pedicle of variable dimensions according to the breadth of its attachments at the side of the orifice which connects it with the lumen of the vessel.

The form assumed by the sac in the process of development, as well as its relations to the parent trunk, depend upon: (1) The original starting-point of the lesion or site of the injury in the arterial wall

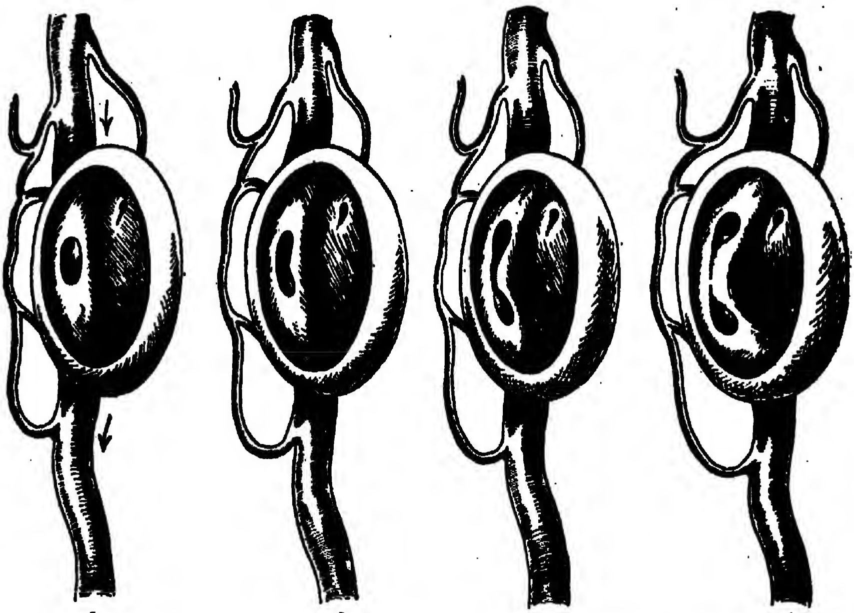

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FIG. 71.—TRANSFORMATION OF A PRIMARY SACCIFORM (SINGLE OPENING) INTO A FUSIFORM SAC WITH TWO OPENINGS LEADING TO THE MAIN TRUNK.
The constant backward pressure upon the artery leads to the stretching of the vessel, with elongation of the orifice until it is gradually made to appear as a double opening.

which serves as a basis for the aneurismal dilatation. It may begin in any part of the circumference of the vessel, anteriorly, posteriorly, laterally, or circumferentially, according to the primary seat or extent of the lesion; (2) the development of weak spots in the primary sac after it has formed, the sac yielding always at the weakest point; (3) the variable resistance of the peri-aneurismal tissues, the sac developing (other conditions being equal) along the lines of least resistance; (4) the direction of the blood-stream or current in the sac, that part dilating most which receives the most direct impact of the systolic wave.

Adaptation to Surroundings.—The sac in the process of formation therefore adapts itself to its surroundings, and the original bipolar

or spindle-shaped outline of the typical fusiform sac, for example, is lost, the tumor rotating upon its polar and equatorial axes as it meets resisting planes which change the direction and, consequently, the force of the blood-stream from one point to another in the interior of the sac. If a fusiform (pathologic) aneurism develops in the peripheral arteries of the extremities, it meets with the resistance of the skeleton and the aponeurotic and other unyielding tissue planes, as in the groin (the pubic plane), in the popliteal space (the posterior intercondyloid and tibial planes), in the neck (the anterior vertebral plane)—which cause the original ovoid sac to flatten on the side which meets with the greatest resistance. It then develops progressively into a sacculated pouch in the opposite direction, *i. e.*, where it meets with the least resistance. It is evident from this that the classic teachings that fusiform aneurisms are not common in the extremities is true only as to the form of the sac when taken in a literal sense, experience showing that the sacs which begin originally as fusiform swellings, with a bipolar formation, are more often found in the extremities than in the central vessels.

In 34 peripheral aneurisms, of which 55 per cent. were popliteal, operated upon by Matas' intrasaccular method, 23 were fusiform and 11 sacciform. It is well known, on the other hand, that two-thirds of aortic aneurisms are of the sacciform type.

The Form of the Sac Not a Guide as to the Extent of the Arterial Disease.—It is also an error to believe that the entire circumference of the artery is diseased when an aneurism assumes a fusiform shape, or that the artery is only partially diseased in those of the sacciform type. Many fusiform aneurisms assume a sacciform shape solely as a consequence of their environment and not as a result of the relative soundness or disease of the arterial parietes. On the other hand, it does happen quite frequently that aneurisms which begin as typical bulgings or pouches at the site of well-defined and circumscribed lesions of the arterial wall (punctured, gunshot, or other exclusively traumatic aneurisms) ultimately assume a fusiform type. The original narrow neck of the sac will gradually stretch as the result of flexion or extension of the limb; a curve or bend in the long axis of the artery, etc.—and dilate until the orifice enlarges to the length of the longest diameter of the sac; the partition or éperon (spur) which originally separated the cavity of the aneurism from the lumen of the artery is absorbed or obliterated. In opening such sacs, instead of the one original opening or neck, the interior will reveal two openings corresponding to the inlet and outlet of the aneurismal pouch. The fact, however, that the sac has assumed the fusiform shape does not necessarily imply a diffused generalized degeneration of the entire circumference of the parent artery. In traumatic and even some pathologic aneurisms, in which the area of degeneration is circumscribed, it will be still possible to recognize the outline of the parent artery in the interior of the sac, as either a deep or shallow, gutter-like groove, which extends from the

outlet to the inlet along the floor of the aneurismal sac. When this is the case, it is possible to reconstruct the parent artery or to restore it by suturing the sac-walls over the groove in a continuous suture from one orifice to the other, with greater probability of permanent success than when this procedure is adopted in fusiform aneurisms in which there is no visible relic of the parent trunk in the sac.

Relation of the Sac to the Parent Artery.—The direction and impact of the blood-stream (coup de bélier (ram) of the French writers)

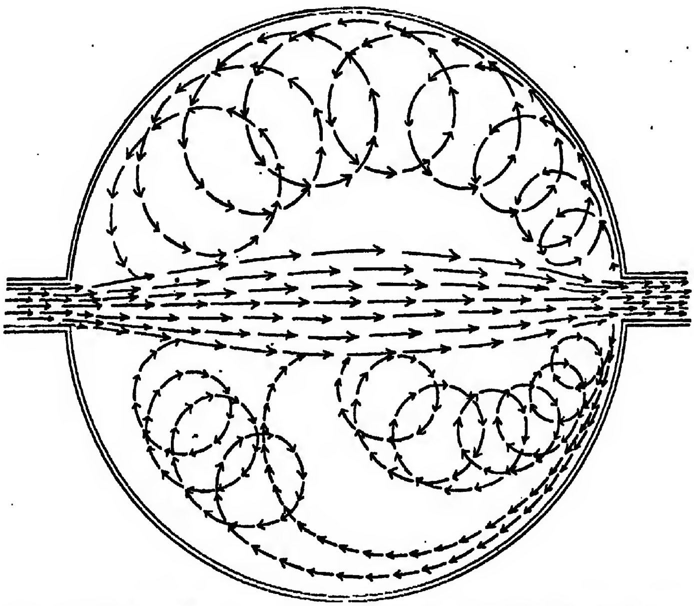

FIG. 72.—THE COURSE OF BLOOD IN ANEURISM. (Ballance and Edmunds.)

The blood is supposed to enter on the left; it then passes straight across the aneurism to the opposite opening or outlet; part of the blood escapes directly out of the sac in this way, the rest returns in eddies around the sides; the arrows and circles represent the varying courses which particles suspended in water can be seen to take in a hollow glass sphere used in the experiment; later they reenter the central stream. Close to the surface of the aneurism are very small eddies. The only effect of making the inlet tube extend in the center of the aneurism is to make the fluid behind the entrance more stagnant. In living aneurisms the direction of the blood-stream in the sac will be determined largely by the fixed longitudinal axis of the artery at the inlet, the greatest distention, expansile pulsation, and final rupture taking place at that part of the sac opposite the inlet. The diagram is utilized solely to show that in the peripheral parts of the stream the fluid becomes more stagnant in the smaller and larger eddies and is, therefore, more favorable for the formation of clot. Apart from this general fact, the conditions represented in a hollow glass sphere do not reproduce those which occur in living aneurisms in which the walls are not rigid and the form of the sac is extremely variable, rarely symmetric, and in which the positions of the inlet and outlet are also most variable and eccentric.

is the most powerful factor in determining the alterations observed in the form of the sac; far more important than the resistance of the perivascular tissues, as is well illustrated in the thoracic aortic aneurisms, which erode and perforate the sternum and ribs when the systolic distention of the sac, due to direct impact of the blood-stream, is directed against the osseous walls of the chest. In the popliteal space an aneurism may bore its way into the knee-joint in spite of the extreme resistance and toughness of the posterior ligament of the joint. But this only happens when the proximal pole of the artery is fixed or per-

manently held in place by peri-arterial adhesions, which do not permit it to adapt itself to the varying resistance of the surrounding tissues.

Rotation of the Aneurismal Sac.—By the different changes observed in the form of the sac as result of adaptation to surroundings, the rela-

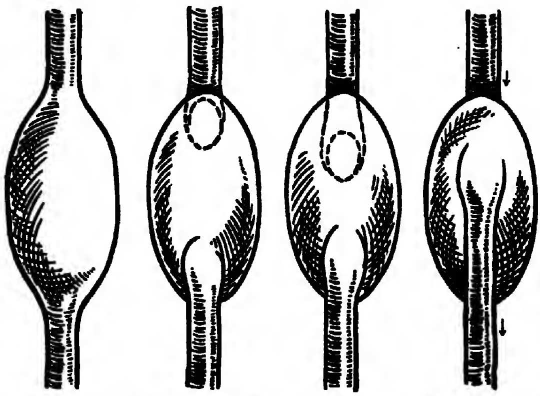

FIG. 73.—STUDIES IN THE ROTATION OF ANEURISMAL SACS. ANTEROPOSTERIOR VIEW OF SERIES. Popliteal aneurism at bend of knee. The afferent trunk lies on the knee side (ventrad); the efferent ascends on the dorsal side (dorsad) (proximal to the operator).

tions of the main artery to the sac may also be notably altered as the aneurismal dilatation progresses. Thus, in an originally fusiform sac, the terminal bipolar implantation of the afferent and efferent trunks may, by a gradual process of actual rotation, be displaced from the

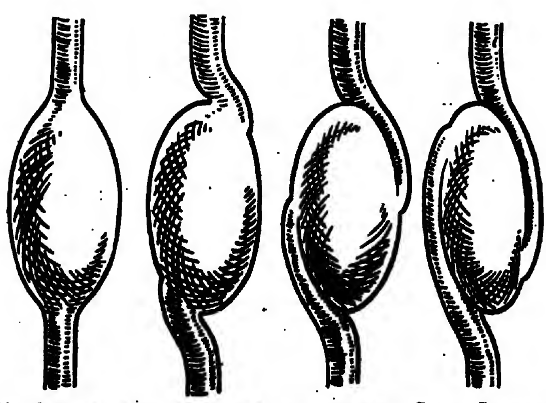

FIG. 74.—STUDIES IN THE ROTATION OF ANEURISMAL SACS. LATERAL VIEW. Backward rotation in a popliteal aneurism at the bend of the knee; the afferent trunk lies on the joint side progressively descending; the efferent trunk progressively ascends on the dorsal (cutaneous) side (proximal to the operator):

polar to the equatorial diameter of the sac, thus accounting for the eccentric and unexpected position of the main orifices in the interior of the sac when this is opened. The relation of the sac and the dragging of its attachments from an original polar implantation to other points of the aneurismal spheroid has only come clearly to light since the

frequent application of Matas' method of intrasaccular suture, as giving better opportunities for the study of the relations of the sac to the parent vessel. The anatomic data thus obtained have a practical bearing on the operative surgery of aneurisms, because, without a knowledge of the probability of aneurismal rotation or transposition of the orifices, the operator may readily *cut into the nutrient or parent trunk* as it lies embedded on the surface of the aneurism right in the path of the knife. A knowledge of these facts will also avoid a long and disappointing search for the nutrient orifices which is reported by several operators, who, expecting to find these orifices at the so-called classic points of attachment, *i. e.*, at each pole of the sac, are surprised to find them in the roof of the sac or other eccentric or unexpected sites. Sometimes, in ignorance of the possibilities of rotation and eccentric implantation of the main artery, the search for these orifices in the interior of the sac has been abandoned, and instead of suturing the orifices with the sac as should be done, the parent trunk has been sought and ligated above and below the sac after considerable dissection and traumatism, thus defeating one of the prime objects of the intrasaccular method, which is to economize trauma and to secure all bleeding points within the sac itself. (See Treatment of Aneurisms.)

In addition to the three fundamental types, the cylindric, fusiform, and sacciform, the sac may also be multilocular or multisaccular, if secondary dilatations and pouches result from the yielding of the primary sac at weaker points. A fusiform sac may also present a series of constrictions indicating the various points where a series of peripheral dilatations have fused with each other, forming a bipartite, tripartite, or multilocular sac. A fusiform sac may also assume an hour-glass shape, the narrow neck constricting both proximal and distal pouches, representing the constriction caused by the passage of the aneurismal trunk through an opening in unyielding tissues. A most striking illustration of this hour-glass type was recently presented by Reichel, who extirpated a femoral-popliteal aneurism, which was divided in the manner above described into two compartments as it passed through the tendinous foramen of the adductor magnus, one-half of the aneurism developing in Hunter's canal and the other in the popliteal space.

The rotation of the sac and the greatest alteration in the form of the aneurism are observed with greatest frequency in those regions in which the main artery is the most subject to disturbance from the proximity to the joints. Hence the greater frequency of anomalies of configuration in the aneurisms in the popliteal space and in the groin. It is also in consequence of the frequent exaggeration in the normal flexion and extension of the movements of the knee that the popliteal artery is the most frequent seat of aneurism in the periphery of the body; the physiologic trauma caused by forcible stretching (in athletes and the laboring classes particularly) in exaggerated tension, contributing no doubt to the localization of the aneurismal disease most frequently in this part of the body when arteriosclerotic or degenerative conditions of the vessel walls prepare the ground for the trauma.

Classification of Sacs for Surgical Purposes.—In view of the variability and inconstancy of the form of the sac, the older classification, based upon the external appearance or form of the aneurism, is no longer available for the needs of the modern surgeon. Furthermore, since the object of the surgeon, in operating directly upon an aneurism by the intrasaccular method, is to disturb the sac from its surroundings as little as possible, in order to spare the collateral circulation to the fullest extent, the dissection of the sac (which alone would permit a differentiation of types by their external form) is not permissible. It is best for surgical purposes to differentiate the fundamental types of aneurisms, not by their outward form, for they cannot be exposed to view, but *by the number of orifices which connect them with the parent artery*. These are recognized only after opening the sac. We would call fusiform aneurisms all those in which there are two distinct orifices of communication with the parent trunk, representing the inlet and the outlet of the aneurism and corresponding to the proximal and distal poles of the original sac. The sacciform aneurisms are those in which the sac is connected with the lumen of the parent vessel by a single direct orifice through which the blood flows in and out of the sac. When this type of sac is opened, its interior will reveal either a single circular, ovoid, or elongated opening leading to the main artery. As the sac has grown as an offshoot of the main artery and is grafted, as it were, on it, the outline of the parent trunk is preserved almost in its totality as a deep groove or gutter leading from one orifice to another. By approximating the edges of this single opening or longitudinal fissure the communication of the artery with the sac is completely obliterated without interrupting the continuity of the vessel or obstructing its lumen (restorative aneurismorrhaphy). In fusiform aneurisms the orifices can be obliterated by suture without interrupting the continuity of the main artery for a distance equal to the length of the space intervening between them.

External Surface; Collateral Branches.—The external surface of a dissected sac will show a number of collateral branches of variable size and number, corresponding in a general way with the branches given off normally by the artery in the aneurismal segment. Other branches not clinically recognizable as normal branches may also develop from small undeveloped trunks which assume collateral functions as the growth of the aneurism progresses. Many of the branches opening into the sac will be found functionless and plugged with thrombi, especially in old aneurisms in which the inner walls have become plastered with many layers of laminated clot. Though many of these collaterals are obliterated in the sac, they anastomose with each other and with the vessels above and below the aneurism in such a manner that a continuous extra-aneurismal circulation is maintained, even though all the branches immediately opening into the sac may ultimately become plugged and functionless. This fact has important bearing in the surgical treatment of aneurism, because the destruction of these peri-aneurismal anastomosing branches involves great risk to

the limb whenever the circulation in the aneurism is interrupted by extirpation of the sac or its obliteration by suture. Hence, again, the important injunction to disturb the peri-aneurismal tissues as little as is consistent with the mere opening of the sac. Whenever it happens that the aneurismal sac (popliteal, for example) becomes partially or completely obliterated by the formation of a laminated clot, the anastomotic network which originates directly from the sac may become functionally useless, and gangrene of the distal parts will occur spontaneously and without surgical intervention. If the peri-aneurismal network is well developed, even though the sac be plugged, including all the collateral vessels originating from it, spontaneous cure will follow without detriment to the peripheral circulation. On the other hand, the perviousness and activity of the collaterals which originate or open in the sac itself also account for the frequency of relapse when only the main trunk is ligated above the sac, as in the Hunterian or Anel operation. It should be remembered also that in fusiform aneurism a much larger segment of the artery is involved at the seat of the aneurism than in those of the sacciform, type which do not involve the entire circumference of the artery. Hence, the prognosis, from the point of view of the vitality of the distal parts, is better in sacciform aneurisms, especially as these can be readily obliterated without interrupting the continuity of the blood-stream. Hence again the importance of treating fusiform aneurisms with the least interference of the peri-aneurismal circulation.

Contents of the Sac.—When an aneurism is first formed, the sac contains only fluid blood. As it develops, the circulation in the periphery of the current becomes less active, especially in those parts where the elasticity of the vessel is totally lost and where the systolic impulse is less felt. In this way blood stasis is favored and followed by the coagulation of blood-plates and leukocytes in the more stagnant areas, leading to the liberation of fibrin ferment and the precipitation of fibrin. A plate-fibrin thrombus is thus formed which is deposited in stratified superimposed layers, constituting the active or laminated clot of Broca. This stratified laminated white clot becomes partially adherent to the sac-wall, and as the aneurism grows older may become organized and permanently adhere to the sac-wall as a pseudomembrane; the organization never being complete, however, but still appreciable in many cases of obliterated aneurism in which the clot has been invaded by fibroblasts and angeioblasts from the adventitia or perivascular connective tissue. Usually the blood-stream finds its way between the lamellæ and interferes with their organization, except in the primitive or oldest layers. In favorable conditions the white clot will be deposited in concentric layers until the sac is filled in its totality, thus excluding the blood-stream and spontaneously curing the aneurism. Or it may fill up the sac circumferentially, leaving only a middle channel from the inlet to the outlet of the sac, thus virtually rendering the aneurism inert, the clot being merely canalized for the passage of the blood-current.

Usually, when an aneurismal sac is opened, it contains fluid

blood with a mixture of white laminated and red or "cruoric" clot, the passive clot of Broca, which cannot be distinguished from an ordinary extravascular coagulum. The difference between the two varieties of clot is that the white thrombus consists of fibrin, blood-plates, and leukocytes, with a few erythrocytes tangled in the fibrin network; while the red clot is made up of all the elements

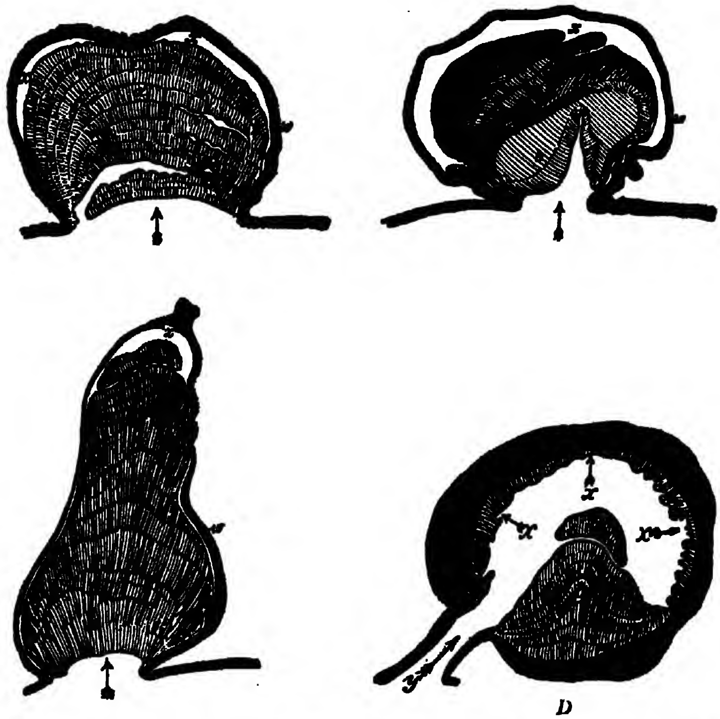

FIG. 75.—DIAGRAMS SHOWING THE PROCESS OF GROWTH OF THE ANEURISM AND THE MODE OF DEPOSITION OF A CLOT WITHIN IT. (Ballance and Edmunds.)

A, the first stage of aneurism. It is a simple sac (*w*) filled with laminated clot (*a*). The space (*x*) between the wall and the clot contains fluid blood and is in communication with the main vessel. *B* and *C*, the second stage. Th portion of the clot first deposited is marked *a*, the later *b*; as the aneurism extends by pressure of the blood, the clot (*a*) is pushed further away from the mouth of the aneurism and a more recent clot is deposited beneath it, as seen in *C*; or the clot (*a*) may become situated on one side in consequence of the unequal extension of the sac, as seen in *B*. *D* shows a yet further stage: *a*, *b*, and *w* as before, but the space (*x x x*) has become much enlarged from the pressure of the fluid blood within it, which is in communicat on with the blood in the artery. The fluid pressure is in all directions as shown by the arrows, but the direction of the growth is modified by the resistance of surrounding structures. By this process the clot (*a*) has been left in this case in the center of the aneurism, and a new layer of clot (*c*) has been deposited on the inne side of the wall (*w*).

of the blood, including fibrin. Usually there is a gradual transition from the laminated stratified clot to the red clot. The white clot is adherent to the walls, where it becomes dry, firm, and compressed. Toward the mouth of the sac it becomes softer and moister and of a reddish color, while that in contact with the blood-stream resembles ordinary soft red clot. The relative proportion of white clot in the sac is dependent upon several causes, chiefly upon the age and form of the sac and the activity of the blood-current within it. The sacciform

aneurism with a narrow neck has the most sluggish circulation and favors most the formation of the clot. In some old sacs or those which have been cured spontaneously, the stratified white clot is arranged in concentric layers which suggest the appearance of a cut onion (Fig. 75). In some of the old obliterated aneurisms the clot undergoes calcareous and other degenerative changes (sometimes forming thromboliths), but this occurs much less frequently than in the thrombi of varicose veins. When the circulation is *suddenly* arrested in an arterial aneurism, the blood coagulates and the sac is filled with a soft red passive clot, which breaks up very easily, often forming emboli, which find their way into the distal artery, causing gangrene or other peripheral disturbances in the circulation.

The relation of the white to the red clot has been a subject of much controversy. While the primitive fibrinous layers are deposited in the interior of the sac as the result of conglutination of blood-plates and leukocytes, the transition or transformation of the red clot into the white is not so apparent. Without entering into the details of the controversy, it would not appear at all incompatible with our knowledge of coagulation that the red clot in the course of time would lose its color by absorption of the hematin and its fibrin remain stratified in concentric layers as the more active current receded from the periphery of the sac. The view that the red and white clot were altogether distinct in their origin was especially upheld by the older surgeons and pathologists, and even lately so eminent an authority as Stimson (1891) regards the transformation of one into the other as highly improbable. On the other hand, Richet, Lefort, Boinet, Hayem, Ballance and Edmunds, and probably the vast majority of modern writers support the transformation theory.

Evolution of the Sac and its Effects upon the Peri-aneurismal Tissues (Pressure Effects).—As the sac develops, a series of changes in the peri-aneurismal tissues are instituted which in time add seriously to the burdens of the original disease. These pressure effects are manifested by a chronic type of irritative cellulitis, in which the connective tissue in the vicinity of the aneurism proliferates and fuses with the outer coat of the sac, becoming condensed and sclerotic by gradual hyperplasia. In this sclerogenic process are also involved the surrounding lymphatics, veins, and nerves, which become stretched, flattened, thinned, and altered by progressive distention. The veins in contact with the sac become in many advanced cases obliterated by a plastic phlebitis, the lymphatics also and the traumatized nerves undergo interstitial neuritis, manifested symptomatically by peripheral neuralgias, paresthesias, and trophic disturbances in the distal parts. Edema of the extremities likewise results from interference with the venous and lymphatic circulation. The bones undergo absorption and erosion as a result of progressive osteoporosis and decalcination.

A most important effect upon the arterial collateral circulation in the immediate vicinity of the aneurism is also exercised by the constantly growing sac. This is especially important in the popliteal region, where the overlying aponeurosis offers great resistance to the expansion of the sac. Here the peri-aneurismal tissues are displaced and laterally crowded en masse toward the unyielding condyles and the

osseous insertions of the hamstrings, gastrocnemius, and soleus, which form the lateral boundaries of the space. The more yielding veins and lymphatics are the last to feel the effect of the compression exercised by the growing sac, then the peripheral collateral arteries, and lastly the nerves. It is easy to conceive that in advanced cases, when the tumor occupies the center of the popliteal space immediately behind the knee-joint, that not only locomotion should be impeded, but that the arterial supply of the leg and foot should be much impaired. In fact, the circulation of the distal parts is then dependent almost exclusively upon the continuity of the blood-stream through the aneurism itself. Any accidental condition or obstructive interference which will bring about an obliteration of the main artery or of the aneurism, such as sudden displacement of a thrombus or a general clotting of the sac contents by a ligature, and will end in gangrene of the peripheral parts. This is the great danger which attends all methods of proximal compression. The ideal treatment is reached when, in addition to the immediate relief of tension, the continuity of the main artery as well as the compressed collaterals is obtained.

In the central organs, the thoracic and abdominal cavities especially, where aortic aneurisms obtain their largest size, the sac in its growth displaces the neighboring organs, contracting adhesions with the surrounding parts. The hollow organs, the trachea, bronchi, esophagus, stomach, the great veins, the cavæ, the pulmonary artery, the auricles and ventricles of the heart, and the thoracic duct are encroached upon, the compression ending by melting away the intervening partition and rupturing into the other organs or splanchnic cavities and thus bringing about a fatal termination by hemorrhage, which may appear as a profuse hemoptysis, hematemesis, or as a concealed hemopericardium, hemothorax, hematorrachis, etc. When the large veins are perforated, pathologic arteriovenous aneurisms are formed which cause great circulatory disturbances from the rapid fall of the blood-pressure on the arterial side as the aorta empties itself into the veins. If the fistulous communication is not very large, a temporary adaptation to conditions will occur which may be tolerated for a time just as congenital malformations of the cardiac septa are fairly well tolerated for a time in early life.

In the thoracic and abdominal aneurisms the compression of important nerves (pneumogastric, phrenic, sympathetic, recurrent laryngeal, intercostals) gives rise to a series of reflex and referred pains which, when properly interpreted by the clinician, not only reveal the presence of an aneurism, but its progress as well.

Terminations.—A few and very rare aneurisms have been recorded in the literature which showed no tendency to grow or develop. In some of these the sac has clotted, leaving a central channel for the passage of the blood. They have continued indolent and latent, sometimes for a period of fifteen to twenty years (Broca). In the end, however, accidental conditions have always caused them to return to activity, compelling active measures for their control or removal.

The natural tendency of an aneurism is to dilate and finally to rupture, either by gradual weakening of its walls or by ulceration into a natural adjoining cavity or through the skin. As it approaches the surface the skin becomes tense, adherent, inflamed, and may ulcerate and become gangrenous. The inflammatory process outside of the sac has been thought to favor coagulation of the blood within it, and thus lead to a temporary or even a permanent arrest of the disease, but, ordinarily, free hemorrhage follows the rupture and requires extreme measures for its arrest, if, indeed, arrest is possible.

The most favorable possible termination is its spontaneous cure by coagulation of the blood within it. The conditions which provoke or favor this occurrence may be classified under three heads: (1) Those which favor clotting in the sac by retardation or arrest of the current through it; (2) those which increase the coagulability of the blood;

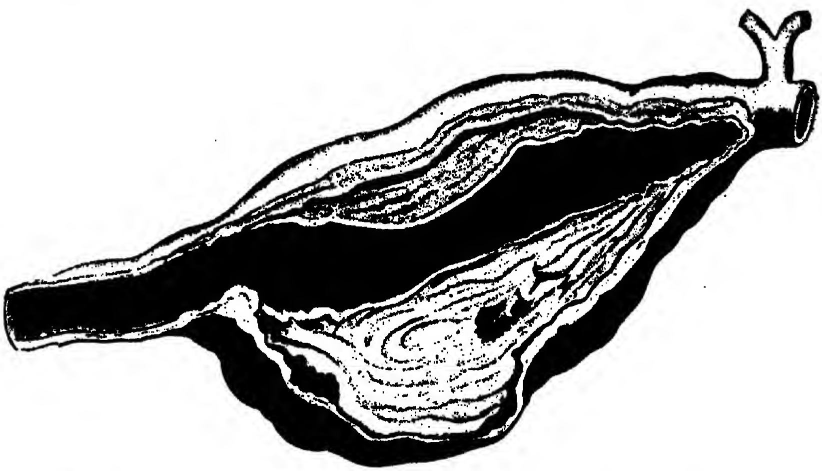

FIG. 76.—SPONTANEOUS CURE OF FEMORAL ANEURISM. (Ballance and Edmunds.)

(3) those which provoke coagulation through changes in or about the walls of the sac (Stimson). All these may be briefly summarized as follows: Spontaneous recovery takes place by (1) gradual deposit of fibrin from the blood in a laminated manner on the walls of the sac, so that the aneurism is completely consolidated and subsequently, by condensation and shrinking, becomes converted into a small, nodular mass of fibrous tissue. The artery, under such circumstances, may remain pervious or become converted into a fibrous cord as far as the first collateral branch above and below the seat of the aneurism. Such a favorable termination may be brought about by the retardation of the blood-current induced by (*a*) the lowering of the heart's action; (*b*) the pressure of the aneurism upon the artery above its opening into the sac; (*c*) partial blocking of the mouth of the sac with a piece of detached coagulum; (*d*) the impaction of a piece of clot in the artery below the mouth of the sac; (*e*) the pressure of another aneurism or a tumor upon the artery above the sac or on the sac itself;

(*f*) the aneurism rupturing and the effused blood compressing the artery leading to the aneurism. (2) By filling of the sac with recent ordinary coagulum as distinguished from the deposit of old-standing laminated fibrin. The coagulation of the blood in the sac may be brought about by: (*a*) the complete blocking of the mouth of the sac by a piece of detached clot; or (*b*) by the complete plugging of the artery above and below the aneurism. The clot may thus become organized and transformed into a fibrous cord. (3) By the inflammation and sloughing of the sac and the plugging of the artery above and below the clot.

While there are so many ways by which an aneurism may be spontaneously cured, the event is nevertheless a very exceptional occurrence. Boinet has collected 60 instances of verified spontaneous cures in aortic aneurism alone; but this mode of termination is not legitimately to be expected. Sometimes, and not very rarely, the spontaneous cure of an aneurism may bring about: (1) Great disturbances in the peripheral circulation, ending in gangrene of the foot and leg in popliteal aneurisms (whenever all the collaterals become plugged with a thrombus); death from intestinal gangrene (duodenum) when a celiac aneurism fills with clot, blocking up the collaterals which nourish the stomach, duodenum, liver, and pancreas; fatal gangrene will also follow in the extremities when an abdominal aneurism close to the bifurcation undergoes spontaneous coagulation—*i. e.*, when it is cured—or uremia may follow the spontaneous obliteration of an aortic aneurism involving the origin of both renal arteries in the sac. (2) Gangrene of distal parts may also follow compression and occlusion of the parent artery by the aneurism itself. (3) More often the sac ruptures, ending in fatal hemorrhage which may become manifest, when the rupture takes place, in one of the hollow organs, esophagus, trachea, bronchus, or remain concealed when the hemorrhage occurs into one of the splanchnic cavities. Three-fourths of abdominal aneurisms end fatally by rupture (Boinet). (4) Death may be caused by a series of small preliminary extravasations which invade the surrounding tissues and bring about the end by anemia, exhaustion, or interference with vital or important organs. (5) Death may occur from asphyxia due to reflex spasm of the larynx or abductor paralysis of the glottis by direct compression of the trachea. (6) By marasmus and aneurismal cachexia (Rénon), especially when the esophagus and the thoracic duct are compressed. (7) Infection and sloughing of the sac, with sepsis and secondary hemorrhage. (8) By the formation of arteriovenous aneurisms which result from rupture into the vena cavæ, pulmonary artery, and other thoracic veins, and may bring about a fatal syncope from acute arterial depletion.

Death as the result of aneurism may occur suddenly or rapidly, or slowly and gradually. *Sudden* death is more often caused by cardiac syncope due to acute vascular depletion and anemia of the brain; by angina pectoris, by glottic spasm, caused by irritation of the recurrent laryngeal or by inhibition of both pneumogastric nerves. Death

may come *rapidly* by asphyxia when the aneurism ruptures into the trachea, bronchi, or respiratory passages; when it ruptures into the pericardium, pleuræ, peritoneum, or spinal canal; by cerebral embolism, by pericardial effusion, hemorrhagic or otherwise, by progressive slow compression of the trachea, or by compression of the atrium of the cavæ or of the auricles themselves. It may come *slowly* or *gradually* by progressive compression of the trachea and bronchi, by compression of the superior vena cava or of the heart itself, by compression of the esophagus or thoracic duct; by causing pulmonary edema and even gangrene of the lungs by obliterating the vessels at the hilum or by favoring marasmus and pulmonary tuberculosis on account of damage to the pneumogastrics, which greatly diminish the resistance of the lung-tissue to infection.

Effects on the Circulation.—Hypertrophy of the left ventricle of the heart, varicose enlargement of veins, obstruction of vessels by emboli discharged from the sac, disturbance in the blood-pressure caused by compression of important veins, thus preventing the blood from reaching the auricles and supplying the pulmonary and general circulation; edema; anasarca from compression and damming back of the venous circuit of the veins; disturbances in the composition of the blood and in general blood-pressure by the formation of arteriovenous aneurisms may follow.

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Symptomatology.—The signs and symptoms of aneurisms vary with their topographic distribution. In some internal aneurisms the tumor may attain full development and even rupture, causing death, and the diagnosis still remain uncertain until the existence of the aneurism is revealed by the autopsy. According to Lebert, fully one-eighth of thoracic aneurisms escape detection during life and are only revealed after a fatal hemorrhage has caused death (Boinet). More often the attention of the patient is attracted to the seat of the lesion

by subjective and functional symptoms even long before any appreciable tumor is recognizable externally. In the peripheral aneurisms, taking the popliteal as the most common illustration, the attention of the patient is directed to the affected part by the pain, swelling, and a feeling of muscular weakness, sometimes by stiffness of the joint. On examination a swelling is discovered in the course of the main artery.

When an aneurism forms suddenly, by rupture or perforation of an artery, or in consequence of a violent effort or emotion, its formation is announced by a sharp pain and the more or less prompt appearance of a tumor if it is in an accessible locality. Usually, however, the aneurism forms slowly and with little subjective disturbance in the incipiency, and the discovery of the tumor is the first event to attract attention.

Physical Signs.—A tumor of variable size develops along the course of the main artery of the region. Its surface is smooth and regular, ovoid or globular in shape. On inspection, it is seen that the mass pulsates and that the pulsations are synchronous with the pulse. The skin over the tumor is normal in appearance and movable. The veins below the tumor, on the distal side, may be turgid, congested, varicose, and the skin in fair subjects may present a marbled appearance. As the tumor enlarges there may be marked edema about the malleoli, foot, or other dependent parts. On palpation, the tumor is found to be non-adherent to the skin, painless to the touch. By manipulations it may be moved slightly in a lateral direction, not at all in a longitudinal direction along the axis of the artery. It is soft, compressible, elastic to the feel when it is of recent formation; hard and tense when it is old and filled with clot. The most notable fact recognized by palpation is the *expansile* character of the pulsation in the tumor itself; that is, when the hand is placed upon the tumor, it is felt to expand in every direction. If it is grasped between the thumb and finger or between the hands, these are not only lifted up, but pushed apart by it. In aneurisms containing much clot, this expansile pulsation may not be so readily obtained, but when present, as it is in the majority of cases, it is a sign of the most convincing character. If steady pressure is applied to the tumor its size may be more or less diminished, but it immediately regains its former volume when the pressure is removed. If the artery on the cardiac side of the tumor can be compressed, the pulsation in the tumor will gradually diminish and cease altogether, the tumor becoming perceptibly smaller and less tense. On removing the pressure it quickly fills again in two or three forcible pulsations and recovers all its former characteristics. This reduction in size and volume of the tumor with arrested pulsation—obtained by compressing the main artery—is, of all the signs of aneurism, by far the most important and characteristic. When well marked, it is pathognomonic of the disease.[1]

[1] The eccentric, expansile pulsation that is so characteristic of aneurism and the friction produced by the eddies and obstruction by clot in the aneurism causes a marked reduction in the arterial pressure beyond, which is often easily recognized at the bedside, constituting an important diagnostic symptom (Ballance and Edmunds, p. 532).

Influence of Position.—If the limb is elevated, the pulsation is less visible, the tension of the tumor relaxes, it becomes softer, and more compressible. If the limb is depressed or lowered vertically, the tumor beats more vigorously, enlarges, hardens, and is less compressible.

"The pressure the blood exerts on the inner surface of the sac is the same on every area, corresponding in extent to that of the sectional area of the artery as it enters the sac. Now, the area of the inner surface of the sac increases as the square of the radius (Holmes, Walsham-Spencer). From these considerations may be gathered the amount of pressure to which the wall of the aneurism is subjected unless strengthened and the area of its inner surface lessened by the clot."

"The pulse below the tumor is smaller on the affected side than on the sound side. The blood-pressure is also diminished as compared with the sound side; in some cases, with little clot in the sac, the difference may be very slight between the two limbs. If a sphygmographic tracing is taken, it shows that the pulse is delayed on the aneurismal side and diminished in force as well; the tracing being less abrupt in its rise and more rounded, the dicrotic notch being less sharp or absent" (Mahomed, Walsham).

On *auscultation*, with the ear directly applied to the tumor, or by listening through a stethoscope, a murmur is heard which is synchronous with the arterial pulse; this is the aneurismal bruit. It may vary considerably in character in different cases and in different regions, but it is usually harsh rather than a soft or blowing murmur. It is usually limited to the tumor itself and rarely propagated beyond it, along the arterial tract or along the blood-current. If pressure is made upon the artery above the tumor, the bruit and all the sounds in the aneurism cease with the arrest in the pulsation. Sometimes a double murmur is heard, one systolic and the other diastolic. Chauveau and Marie account for the aneurismal bruit by the vibrations of the blood-stream in the interior of the sac as it passes from a narrower to a larger channel. The murmur is loudest at the point where the artery enters the sac. Vibratory thrills, so characteristic of arteriovenous aneurisms, are extremely rare in arterial aneurisms.

X-Ray Examinations.—In the peripheral aneurisms, the presence of marked arteriosclerosis with calcareous change can be demonstrated by radiographs which show diseased arteries as faint or dark shadows (linear shadows), corresponding to the outline of the vessels (Carl Beck, Imbert, Lamy). Old aneurisms with atheromatous and calcareous walls or containing much clot show as deep pulsating shadows directly recognizable with the fluoroscope. The form of the sac, its size, relation with the afferent and efferent vessel, activity of its circulation, judging by the degree of expansion and the amount of clot contained in it, can all be ascertained by fluoroscopic examination. The Röntgen rays have been most valuable in aiding the early diagnosis of internal aneurisms, especially those of the thoracic aorta. Thanks to this great help, an aneurism which is merely suspected by the clinical signs becomes readily demonstrable through the screen. In examining

for aneurismal disease the fluoroscope is far more useful than the radiograph. The x-rays not only aid in the diagnosis by locating the tumor, but also in the prognosis by showing the reduction or increase in size of the tumor in the course of the treatment (gelatin injections, etc.). Baetjer (1895) and Krause (1896) have developed a special technic by which the differential diagnosis can be better made between aneurism and other mediastinal tumors.

The exploration of the chest for aneurism by the x-rays, if it is to be at all complete, must comprise at least four successive views in different positions of the patient: an anterior, a posterior, a lateral, and especially an anterior right oblique, as insisted upon by Holzknecht, are indispensable. It is important that the patient should also be examined while turning slowly and standing, in order that the thorax may pass gradually through the various phases of these successive examinations in regular order. The descending portion of the thoracic aorta is the least satisfactory because its shadows merge so completely with those of the vertebral column.

Subjective and Functional Signs.—In the peripheral aneurisms, pains radiating from the aneurism to the periphery, numbness, paresthesias, etc., are complained of as the result of stretching, compression, and inflammation of the nerve-trunks; edema and other evidences of obliterated venous and lymphatic circulation have already been referred to. In the internal aneurisms, especially the thoracic and abdominal, many of the most typical signs previously described as characteristic of the *external* aneurisms cannot be recognized on account of the inaccessibility of these aneurisms until the terminal stages have been reached. There is no appreciable tumor until late in the progress of the disease. On the other hand, a group of pressure signs develop which soon direct the attention of the clinician to the chest, and with the help of x-ray examinations, lead to comparatively early diagnoses.

The more characteristic signs by which the internal and especially the thoracic aortic aneurisms are recognized are dulness on percussion over the region occupied by the tumor; pulsation transmitted to the surface by the underlying aneurism, usually under the sternum or ribs; aneurismal bruit; bronchial breathing and other signs of compression of the trachea, bronchi, or lungs; visible enlargement and turgidity of the veins of the neck and arm; edema of the arm and neck in compression of the superior cava or innominate; pain referred from the level of the aneurism to the surface along Head's zones; or peripheral neuralgia caused by compression of the intercostals, especially marked in lower thoracic aneurisms; reflex pains and coughs caused by compression of the recurrent laryngeal; laryngismus stridulus, dysphonia, or even aphonia, edema of the glottis, paralysis of the vocal chords, usually unilateral, and strident cough, may be all grouped as the laryngeal signs of thoracic aneurism; vasomotor disturbances, unilateral miosis, or mydriasis, and accelerated cardiac action result from compression of the sympathetic; singultus, dyspnea, from compression of the phrenic; vomiting, disturbances of the esophagus, and dysphagia

may result from compression of the esophagus directly or from pneumogastric paralysis; oscillations in the rhythmic pulsation of the trachea and larynx in aneurisms of the transverse arch, tracheal tugging (or the Oliver-Cardarelli sign), result from the transmission of pulsations of the aneurism to the left bronchus where it touches the aorta on its way from the root of the heart to the posterior mediastinum; marasmus, etc., resulting from the compression of the thoracic duct (very rare).

Signs of Rupture.—When an aneurismal sac ruptures, the event may be recognized by a variety of manifestations according to the region and the artery involved. If the rupture is external, the diagnosis will be self-evident; if it occurs in a serous cavity, the signs of acute vascular depletion, acute anemia with prompt and fatal syncope, will at once suggest the concealed hemorrhage, which, if the patient survives long enough, may be confirmed by a physical examination, showing the presence of fluid in the pleura, pericardium, or peritoneum, according to the seat of the rupture. If rupture takes place into the trachea, hemoptysis follows; into the esophagus, hematemesis; into the intestinal canal, enterorrhagia, if the patient lives long enough; if into the pericardium, all the signs of acute heart compression (" Herz tamponade "). If the extravasation takes place in the tissues, all the local signs of extravasation with the formation of hematomata—usually diffuse, progressive, and associated with all the signs of vascular depletion, ending in syncope—will follow.

Aneurisms undergoing spontaneous cure are recognized by the gradual or rapid diminution of all the physical and subjective signs, reduction in size, increased hardness, suppression of murmurs, pulsation, and other signs of circulatory activity in the aneurism.

Differential Diagnosis.—When a typical arterial aneurism presents all or most of the symptoms and signs previously described, the diagnosis is simple, easy, and unmistakable. When an aneurism is filled with clot, or its external and accessible surface is well lined with laminated clot, and the pulsation is not expansile and no murmurs are heard, reduction in size on compression may still guide the surgeon to a diagnosis. But, as Delbet says, there is probably no other disease which exhibits such a long list of celebrated diagnostic errors.

In the diagnosis of arterial aneurisms they should be distinguished or differentiated: (*a*) From other aneurisms, and (*b*) from other allied tumors. From other arterial diseases: from *arteriovenous aneurisms* by the absence of striking disturbances in the venous circulation, the lack of pulsation in the veins, the absence of thrill and loud purring, vibratory murmurs transmitted widely along the proximal and distal veins; from *cirsoid aneurism*, by the fact that these are composed of numerous pulsating vessels, a congeries of arteries and dilated veins, not an isolated tumor over a large surgical artery; by the fact that cirsoid usually occupies the scalp, and by the fact that the ligation or compression of the main artery does not arrest the pulsation of the mass or reduce the bulk of the swelling. From *cavernous angeiomata* aneurisms are distinguished by the absence of expansile pulsation in

the angeiomata; by the slight impression produced upon the size by compression of the main artery; by the fact that angeiomata, as a rule, are subcutaneous and involve the skin, causing a distinct discoloration, and convey to the tactile sense an unmistakable sensation, similar to the emptying of a sponge upon compression. *Serpentine dilatations* or *ectases* of isolated arteries, such as are seen in the arms of thin, aged, arteriosclerotic subjects, are not to be confused with aneurismal swellings because the artery is simply tortuous throughout its length, but shows no distinct sacculations. *From other tumors or swellings:* (1) Transmitted pulsation in tumors. A hard tumor, such as a mass of enlarged and adherent glands in the neck, may simulate an aneurism by transmitting the pulsations of the carotid to the surface. The history of the case, the absence of *expansile* pulsation, non-reduction of the tumor by compression of the artery on the proximal side, mobility of the tumor, which can sometimes be lifted up from the artery, will usually suffice to clear the diagnosis. (2) *Pulsating abscess.* This may be (*a*) a peri-aneurismal phlegmon; (*b*) an abscess into which an eroded artery has ruptured, transforming the cavity into a spurious aneurism or pulsating hematoma; or it may be (*c*) an aneurism which has become infected and is suppurating. In either of these three cases the history is of great value for the diagnosis. But the greatest errors have been committed in connection with infected and suppurating aneurisms, which have been mistaken for ordinary phlegmons or abscesses, especially in the popliteal space. When an aneurism inflames, the peri-aneurismal connective tissue quickly participates in the phlegmonous process, the skin reddens, becomes edematous and infiltrated, hot and tender to the touch. The outline of the aneurismal sac then is lost in the general swelling and cannot be felt through the edematous skin, the whole region throbs and pulsates, but the heaving expansile pulsation is lost, as it is diffused throughout the swelling. It is easy then to fall into error and to plunge a knife into the supposed abscess cavity unless advised by the previous history. Some of the most dramatic episodes recorded in surgical history are connected with just such mistakes. Eminent surgeons, like Desault, Pelletan, Dupuytren, Boyer, Holmes, Pirogoff, Küster, and a host of others too numerous to mention have given proof by their mistakes of the extraordinary difficulty attending the diagnosis of some of these aneurisms. In view of the fact that all the conditions above mentioned require prompt surgical intervention, it should be the rule that in all distinctly pulsating abscesses occurring in important surgical regions, in which a mistake might prove fatal through hemorrhage, every precaution should be taken to procure a bloodless field at the time of the intervention. In the limbs the circulation should be controlled by the Esmarch constrictor; in the neck, the main artery should be exposed, clamped, or provisionally held in a traction loop; in the groin, gluteal, iliac, or axillary regions, the common iliac or subclavian respectively should be exposed and held securely, pending the exploration of the suspicious swelling. There is no reason why, at the present day, except as the

result of hasty diagnosis or inadvertence, such disastrous occurrences as have been recorded in the past should take place.

Telangiectatic sarcomas, endotheliomas, and epitheliomas, especially when developing in bone, are often pulsatile and expansile, thus simulating aneurisms; in fact, aneurisms in bone do exist, but in these, while the pulsation in the tumor is stopped by compression of the main artery, the bulk of the mass remains with little reduction in size. In these cases, as in those previously referred to, a preliminary exploration, after ischemia has been obtained by elastic constriction, will promptly clear the diagnosis without peril to the patient. *X*-ray examinations (fluoroscopic) will also help to reveal the character of the tumor as well as its relation to the bone.

The chief interest in the differential diagnosis of aneurism lies: (1) In the possibility of cutting into an aneurism by mistake, and causing disastrous hemorrhage before the bleeding can be arrested. (2) In preventing amputations and mutilations for supposed malignant tumors of the extremities, which would have been avoided had the diagnosis of aneurism been suspected. (3) By modifying the prognosis, which would be more favorable in aneurism than in sarcoma or carcinoma, or vice versâ, a favorable prognosis might be given under the impression that the tumor is a simple fibrolipoma or fibroma, when on exploration it would be discovered to be an aneurism. Under the prevailing conditions of operative surgery, all of these errors can be readily avoided by direct preliminary exploration at the time of intervention if the surgeon would only bear in mind the possibility of aneurism and prepare himself thoroughly to meet it should the exploration reveal its existence.

The diagnosis of aneurism is not completed by the mere recognition of its existence; the patient must be thoroughly examined with a view to obtaining cognate data which bear directly upon the prognosis and upon the selection of the proper treatment. If possible, an effort should be made to determine the topography of the sac, its size, the activity of its internal circulation, the amount of clot it contains, shown by the degree of compressibility, the vigor or feebleness of the expansile pulsation; the effect of compression of the main artery upon the mass, the effect upon the peripheral circulation obtained by such compression—all valuable, if not indispensable, information for the guidance of the surgeon in his selection of the best method of intervention.

It is also necessary to determine the condition of the general circulation, the heart, the peripheral arteries, as regards arteriosclerotic changes, or the possible coexistence of aneurism elsewhere, in order to estimate not only the probabilities of developing the collateral circulation after the obliteration of the aneurism, but also the general fitness of the patient for the operative act itself, if such is indicated.

Prognosis.—An aneurism—no matter where it may be or how small it may be—is always a serious menace to the bearer. If neglected, it is a menace of death. While spontaneous cure or persistence as a

stationary or latent condition for indefinite periods of time do occur, these are such exceptional events that they are not to be reckoned with in practice. The regular tendency of an aneurism is to enlarge without cessation until it ruptures. Hence the necessity of treating them from the moment they are recognized (Delbet).

The prognosis varies according to the situation of the aneurism. The external aneurisms or those accessible to the surgeon offer infinitely better prospect of recovery than the internal or visceral aneurisms.

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Etiology.—The Relative Incidence of Aneurism.—In a collective study of the surgical diseases as they prevail in the Charity Hospital of New Orleans, I have gathered the statistics of aneurism as recorded in that institution from the decade 1884–1893 inclusive. During this decade 64,421 patients of all classes, suffering from all diseases, were admitted to the Charity Hospital; of these, 70.15 per cent. were of the white race and 29.85 per cent. were colored. During this time 199 aneurisms were recorded, of which 143 occurred among the whites (71.86 per cent.) and 56 among the colored (28.14 per cent.).

Holcombe, at my suggestion, subsequently compiled the statistics of aneurism as recorded in the same institution, during the decade from 1896–1905 inclusive. During this period 81,242 patients were treated, of whom, approximately, 30 per cent. were colored. These yielded 172 cases of aneurism, which were distributed regionally as follows: Thoracic aorta, 70; abdominal aorta, 36; popliteal, 21; femoral, 10; innominate, 9; subclavian, 8; common carotid, 5; external iliac, 2; brachial, 2; axillary, 2; vertebral, 1; ulnar, 1; radial, 1; celiac axis, 1; splenic, 1; occipital, 1; temporal, 1.

Stimson's statistics, based upon the records of the New York Hospital for the years 1882–1892, show that of 22,197 patients admitted to that institution during these ten years, 55 were cases of aneurism, classified as follows: Aorta, 37; innominate, 3; femoral, 3; radial, 3; brachial, 4; cirsoid aneurism, 5. In an analysis of 103,060 autopsies, held from 1865–1900 at the Jena Pathological Institute, E. Müller found record of 183 aneurisms. In 1928 autopsies held at the Boston City Hospital, 36 aneurisms, or 1.8 per cent., are recorded. At the Johns Hopkins Hospital 25 aneurisms were found in 1800 autopsies (Camack).

The real incidence of aneurism in its broadest sense is not easy to determine accurately, because numerous aneurisms of cerebral, pulmonary, visceral arteries, and also many traumatic aneurisms, are classified under different headings in the hospital records, such as

apoplexy, tuberculosis, and under wounds of arteries, etc., and in this way are eliminated from the statistics. However, the statistics above quoted confirm in a general way the experience of observers all over the world, showing that the aorta is by far the most frequent seat of this lesion. The popliteal is next in order of frequency, with 25 per cent. (Crisp) of all aneurisms and 55 to 60 per cent. of the peripheral cases (Matas).

Age.—Arterial disease in children under six years, even the congenitally syphilitic, is practically unknown. In those from six to fifteen years it is rare (Camack). Pathologic aneurisms, therefore, are extremely rare in children. In 1799 autopsies of foundlings at the New York Foundling Asylum, no aneurisms were found (Nicholl, quoted by Camack). Schmidt, however, reports radial aneurism in an infant eight weeks old; Syme, a popliteal aneurism in a boy seven years of age; Hodgson, an aneurism in the carotid of a girl aged ten years. By combining the statistics of Crisp, Lebert, Liddell, Lisfranc, Ruehle, and Lutlich, F. Fischer found that in 2196 cases of aneurism the disease occurred with the greatest frequency between the fortieth and fiftieth years (622 cases); in 41, it occurred before twenty; in 39, after seventy. E. Müller, in his study of the 183 aneurisms, found that only 1 per cent. occurred up to the fifteenth year.

Sex.—Arterial aneurism is largely a male disease (78 per cent.). It occurs more frequently in males up to the fourth or fifth decade; after the fifth decade both sexes are equal (35 per cent.). In Müller's 183 aneurisms, 108 occurred in males and 75 in females. In 280 autopsies collected from literature, Camack notes 210 males and 70 females.

Race.—Aneurism is a disease peculiar not only to man, but to civilized man. It is practically unknown in the lower animals, except as a parasitic manifestation (strongylosis in the horse); this harmonizing with the fact that arterial disease in general is almost unknown among the lower animals. Aneurism in the pathologic sense follows in the wake of arterial diseases and is to be found wherever the conditions which favor arterial degeneration prevail. Its relative frequency as a product of disease is dependent upon the mode of life, habits (indulgence in vascular poisons, alcohol, tobacco, etc.), certain general infections (especially syphilis), and other peculiarities of the race which directly or indirectly influence the health of the arteries. Whatever will prevent premature arteriosclerosis in any of its forms, using the word in its broad generic sense, will also prevent aneurism. The savage races and primitive peoples removed from the touch of civilization enjoy, as far as we know, the same relative immunity from aneurism that is observed in the lower animals. The sins, vices, luxuries, and worries of civilization clog the arteries with the rust of premature senility, known as arteriosclerosis or atheroma, which is the chief factor in the production of aneurism. The Anglo-Saxon and North Celtic races have been reported to be especially liable to aneurismal disease, more so than the Latin races, because of the greater indulgence

in alcoholic intoxicants, as well as the abuse of athletic exercises. All races, however, are equally liable when the same conditions of life and social environment prevail.

The American negro slave, before the Civil War, living under the vigilant eye of the master, was sober and protected to a large extent by social and disciplinary restrictions from the great vascular poisons, alcohol and syphilis; and then aneurism was comparatively rare in the colored race. Since emancipation, license has followed freedom, and now the negro is not only the pathologic peer, but the superior, of his former master in his liability to aneurism as well as to other diseases dependent upon vascular degeneration. Statistical evidence shows that the colored race in the United States is affected with aneurism about four times as frequently as the white (Camack).

Number.—Aneurisms are usually single, but two or more may occur in the same individual or in the same artery. In the congenital dystrophy of the arteries described by Eppinger, Rokitansky, and others, aneurisms appear not only in early life, but in many arteries of the same individual. Much more often, the multiplicity of aneurisms is the result of arterial weakness or disease acquired in adult life—a true aneurismal diathesis. Some of the victims of this diathesis develop aneurisms wherever the slightest traumatism is inflicted upon the arterial walls. Digital compression, traction upon an artery with a loop ligature, a provisional or permanent ligature, and forcipressure, suffice to develop an aneurism. In some cases as many as thirty (Manec) and sixty-three (Pelletier) multiple aneurisms have been counted upon the same individual.

Multiple aneurisms are usually more frequent in the large arterial trunks, especially the aorta (31 were multiple in 340 aortic aneurisms, Boinet). Multiple small aneurisms characterize that rare and fatal form of arterial disease first described by Kussmaul, Maier (1866), by the name of polyarteritis nodosa, in which small aneurisms are strung like the beads of a rosary on the mesenteric or other splanchnic arteries.

The **size** as well as the form of aneurisms is exceedingly variable. While not always true, it may be said that the size of an aneurism is usually proportional to the caliber of the artery to which it is attached. In many of the cerebral vessels aneurisms may never attain a larger size than that of a millet seed. In other vessels, as in the thoracic or abdominal aorta, aneurisms may be as large as a fetal head. When aneurisms attain a very large size, the original sac has long since ruptured or yielded in some part of its surface. By yielding or rupturing in this way, diverticula or secondary pouches are formed, made up of fibrous connective tissue and generalized clot.

Pathogeny.—As shown by statistics, aneurism is most frequent at that age when the coats of the artery are most liable to be weakened by disease, syphilis, and alcohol, and the muscular system is still vigorous. Hence the frequency of aneurism among those whose occupation subjects them to sudden, violent, or irregular strain, such as soldiers, sailors, porters, laborers, and in men so much more than in women.

It is the loss of the middle or musculo-elastic tunic by disease and degeneration which impairs and finally destroys the elasticity of the arterial wall and allows it to yield to the pressure of the blood-stream. Therefore, as Bouglé says, the study of the pathogeny of aneurisms resolves itself into an analysis of the causes which bring about this primary defect of the media. To account for this change various theories have been suggested, of which the best known are:

I. The *inflammatory* or *infectious theory* of arteritis, according to which the disease begins as a proliferative perivascularitis of the vasa vasorum, starting in the external tunic and secondarily affecting the media through obliterative nutritive disturbances, the process being started by a toxemia or bacteriemia, usually of syphilitic origin.

II. The *mechanical theory* of Manchot (1890), based upon observations of previous observers, teaches that the elastic fibers of the media may be primarily ruptured by any muscular overstrain which would bring about a sudden violent increase in the arterial tension. These authors believe that this can take place in normal arteries not previously weakened by disease.

Traumatism.—Barring the false aneurisms (aneurysma spurium) resulting from perforating or penetrating wounds of arteries, the influence of traumatism in the production of aneurism, without coincident arterial disease, has been the subject of much controversy, doubt, and experimentation. It is now well known that with the exception of arteriovenous aneurisms, which in very recent times have been experimentally produced in animals by improved technical methods, the experimental production of typical aneurism by traumatism is practically impossible and has always failed in the lower animals, especially dogs and rabbits, these animals, as is well known, being apparently exempt from arterial disease. Later experiments made by Fabris (1901) were more successful. All this evidence shows that in animals, at least, traumatisms alone will not cause pathologic aneurism unless degeneration (inflammation) of the media is superadded.

III. *The Arteriosclerotic Theory.*—Thoma and his followers attack the mechanical theory, claiming *a priori* that the elastic and muscular fibers of the media in a normal vessel are able to bear any strain occurring in life, no matter how great. Thoma tries to prove by numerous experiments on dogs that the intima can be subjected to an intra-arterial pressure amounting to 100 to 200 cm. Hg. without producing the least microscopically appreciable damage. On the other hand, vessels degenerated by arteriosclerotic processes show enormous lacerations and ruptures when subjected to the same or much less pressure.

It is evident that all three factors, inflammation or infection, traumatism, and degeneration, are all frequently united in the exercise of the same deleterious influence upon the elastic and muscular elements in the media. That arteriosclerosis, in its broad generic sense, is the precursor of aneurism in the vast majority of cases cannot be doubted. The causes that lead to arterial degeneration in general have been already referred to in the chapter on Diseases of the Arteries. It is usually conceded that syphilis, alcohol, and hard labor combined are the most certain predisposing agents. As Osler pithily puts it,

Venus, Bacchus, and Hercules are to be recognized as the etiologic trinity in the causation of aneurism. In fact, without syphilis to account for aneurism at the prime of life, there would be no aneurisms (pathologic) in the great majority of cases, so enormous is the percentage of the syphilitic; at least 70 per cent. of aortic aneurisms are syphilitic.

Experimental Aneurisms Obtained by the Production of Toxic Arteritis.—The physiologists, however, have succeeded in obtaining positive results by injecting adrenalin and other toxic substances. Reference has already been made in the chapter on Diseases of the Arteries to the production of toxic non-inflammatory degeneration of the media obtained by adrenalin injections, and the conclusion expressed that the burden of evidence was in favor of regarding these lesions as identical with those of human arteriosclerosis. To contribute further to the analogy it has been found that multiple aortic aneurisms may be produced in rabbits by this same means. After the adrenalin injections have been administered for some time, circumscribed bulgings are noticed in the arch and the thoracic aorta. Generally, and in the most typical cases, well-developed saccular aneurisms are found. Even aortic ruptures with dissecting aneurisms are reported by Fischer.

The *pathogeny of aneurism*, as viewed in the light of modern evidence, may thus be summed up in a modified statement from His' recent contribution on the subject:

(1) Aneurisms are formed as a result of the permanent disproportion or disturbance of the normal balance between the intravascular pressure and the resistance of the vascular walls.

(2) The resistance of the arterial walls is chiefly dependent upon the integrity of the media, especially its elastic elements.

(3) Any influence which temporarily or permanently destroys the integrity of the elastica may give rise to aneurismal dilatation, unless the power of resistance of the walls is reëstablished by a compensatory process. In certain cases congenital hypoplasia probably plays a part.

(4) The integrity of the elastica and muscularis may be impaired by traumatism or inflammation. It is probable that an entirely healthy artery may be ruptured by external high arterial pressure, especially in combination with traction and contusion.

(5) It has been determined by observations upon human subjects as well as animals that under certain conditions even extensive ruptures may heal without giving rise to symptoms; but in man at least permanent and progressive sac formations are also apt to occur. Traumatism is, however, a determining factor in the formation of aneurisms when it is added to diseased arteries.

(6) The spontaneous formation of aneurisms is favored by all influences which destroy the elastica of the tunica media, such as ischemic foci, infarcts of bacterial and non-bacterial origin (Ponfick), and inflammations of various kinds. These include mycotic embolic aneurisms, perhaps the relatively more common form in children; in

rare cases, tuberculosis, perhaps malaria, and often, probably in the majority of all cases, *syphilis*, which produces a characteristic endarteritis readily distinguishable from the non-specific arteriosclerotic endarteritis.

(7) It has not yet been positively ascertained whether or not, besides the traumatic and inflammatory aneurisms, other forms occur based upon a purely mechanical foundation (elastic and muscular overstrain), as conceived by Thoma; or upon a degenerative, perhaps autotoxic, soil, similar to the adrenalin aneurisms of rabbits (aneurisms in gouty and arthritic subjects).

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Treatment.—The treatment of aneurism may be conveniently divided into the *medical* and the *surgical*. The medical treatment is reserved for the internal aneurisms, which, at present, are not only inaccessible to the surgeon, but even when they are accessible to direct operative intervention, involve certain areas of the circulation which are so vitally necessary to the life of the organism that their obliteration by radical operation would be followed by certain and immediate death. In these cases, measures of treatment may be adopted which, imitating the spontaneous or natural modes of cure, may succeed in arresting the progress of the disease or at least in palliating its most painful and distressing manifestations. The only aneurisms that remain in the absolutely non-surgical category are those of the thoracic and of the abdominal aorta, especially those which occupy the trans- and subdiaphragmatic segments of this artery. With anesthesia, asepsis, and improved methods of hemostasis, the strictly speaking medical aneurisms have been circumscribed to the limits of the aortic tracts above referred to.

Here, however, it would appear that the advance of surgery must halt. For, even with the most ideal methods of approach, and granting that without long delay it will be possible to open the thorax as safely as we now open the abdomen, there will always remain a group of fusiform, cylindric, and dissecting aneurisms involving the entire circumference of the arch and other sections of the aortic tract, in which a radical operation, in the surgical sense of removing or obliterating the diseased artery, will mean death. It is easy to conceive that continued improvements in the methods of artificial respiration on the lines of the Sauerbruch cabinet and methods of positive insufflation (Brauer's, O'Dwyer's, or my own pump), the mediastina may be opened without pneumothorax or serious interference with the respiration; but apart from the exploration of the aneurism, its type, and its relations to the surrounding parts, the diseased sac could not be extirpated or obliterated without arresting the whole systemic circulation. Even granting that two-thirds of the aneurisms of the aortic arch are of the sacciform type, it will be only in exceptional and extremely favorable sacciform cases with a narrow neck that it will be possible that a sacculated aneurism may be obliterated or excised without interrupting the circulation. On the other hand, there is good reason to hope that with increasing facilities for the early recognition of aneurismal dilatations (x-rays), before the complete and irremediable ruin of the arterial coats has been accomplished, it will be possible to institute such hygienic, constitutional, and therapeutic treatment that will arrest the degenerative process and prevent the formation of these inoperable aneurisms.

Medical Treatment.—The object of this treatment is to imitate nature's mode of cure by: (1) Diminishing the blood-pressure; (2) retarding the velocity of the circulation; (3) increasing the coagulability of the blood; (4) provoking thrombus-formation within the sac by agents which act directly on the aneurismal tissues from within and from without. These indications are best met by the dietetic, hygienic, and medicinal treatment which was introduced by Valsalva and Albertini (1728), Tuffnell and Billingham, and is still known by these names. They all aim at accomplishing the first three indications in nearly the same way. The original Valsalva treatment consisted in *absolute* physical and mental rest, in rigorous diet (125 grams of food per day), deprivation of fluids, and repeated bleeding (venesection), by which the volume of blood was reduced, the blood tension diminished, and the coagulability of the blood increased. The treatment was continued until the patient was too weak to lift his hand from the bed. In Tuffnell's treatment (1864) the spoliative venesections are omitted; circulatory and other drugs are given, which accomplish the same results without depreciating the vitality of the patient or crippling his resistance. Neither are the extreme restrictions in diet, so much in favor in the past, now regarded as necessary, especially if the treatment is likely to be of long duration. The ordinary medical régime should be, above all, prolonged and absolute rest in bed; avoidance of all excitement and worry; a fish or similar light diet, with as little fluid

as is actually bearable and is consistent with the proper movement of the bowels. Tuffnell's diet (1864) is an extreme measure, which if consistently carried out imposes a very severe hardship upon the patient. It consists of: *Breakfast*, bread and butter, 60 grams (2 ounces); milk, 60 grams (2 ounces); *dinner*, meat, 90 grams (3 ounces); bread and potatoes, 60 grams (2 ounces); water or claret, 120 grams (4 ounces); *supper*, bread and butter, 60 grams (2 ounces); tea, 60 grams (2 ounces). An absolute or modified diet is preferable because it eliminates the tea, meat, and wine, which are objectionable in the Tuffnell dietary. Tuffnell's treatment should be kept up for three weeks at a time. In its place Sir Douglas Powell advises a fat diet, because it results in the formation of lecithin, which, according to Woolridge, is possessed of marked coagulative properties. Meats, according to Huchard, are particularly objectionable in aneurism-diet, since they lead to the formation of alimentary toxins, which are vaso-constrictor poisons and increase arterial tension. Rest in a horizontal position reduces the pulse eight or ten beats per minute, and on this assumption the impact of the blood against the aneurismal walls will be lessened by 9600 beats in sixteen hours (Boinet). Furthermore, the horizontal position reduces the general blood-pressure 10 mm. Hg., and in this way rest is really the foundation of all medical treatment.

Medicinal Treatment.—Drugs are chiefly indicated to reduce the frequency of the heart-beat and to diminish the arterial tension. Nitroglycerin, tetranitrite, sodium nitrite (Huchard), chloral (Cherchovsky), aconite (Grimshaw), veratrum viride, etc., are all valuable when the pulse is rapid and the arterial tension is high. Potassium iodid, of all the drugs recommended for aneurism, is by far the most potent and useful. While it is especially indicated in all cases in which there is an antecedent syphilitic history, its action in relieving pain and quieting the distress of aneurisms is not dependent upon its antisyphilitic properties. Its mode of action has been diversely interpreted, but whatever this may be, it reduces the tension in the aneurism and favors coagulation. In syphilitic cases it should be combined with a positive mercurial treatment in view of possible syphilitic arteritis. Potassium iodid should be given with judgment and in such doses that the patient may tolerate it without iodism. It should be given in 5 to 10 minims of saturated aqueous solution, gradually increased to 30 or 40 and more three times daily, for at least three or four weeks, this treatment to be discontinued when iodism develops. Surgical patients, unless syphilitic, should not be subjected to the iodid treatment.

Vascular Astringents and Coagulants.—Of the numerous astringents and coagulants formerly prescribed, none remain except the names, as past memorials of this anti-aneurismal materia medica.[1] The only remedies of this class that deserve consideration are *gelatin* and

[1] Rosenfeld has recently tried stagnin as a coagulant hypodermically, with some improvement in 3 cases.

calcium chlorid (Wright), either of which may be given separately internally, but are more conveniently and positively administered together by hypodermoclysis, with the sole view of favoring the coagulation of the blood.

Gelatin.—In 1896 Dastre and Floresco demonstrated the remarkable action of gelatin in hastening the coagulation of the blood. Lancereaux (1901) and Paulesco introduced and systematized the administration of gelatin for the treatment of internal aneurism. The solution recommended by Lancereaux does not exceed 3½ per cent. gelatin dissolved in 0.7 per cent. sodium chlorid solution. The stronger gelatin solutions have shown no advantages over the weaker percentage recommended by Lancereaux. Six to eight ounces of Lancereaux's solution should be injected subcutaneously in the lumbar, subscapular, or upper gluteal regions every five or six days, and continued until twenty injections have been given. Jaeger has collected 120 cases from the literature treated by this method, in which 40 were decidedly improved or apparently cured. Bollenstein (1904) also reports 126 cases, showing favorable results following the gelatin injections in 58 cases (46.03 per cent.), a far higher percentage than obtained by any other method of treatment.

The injection of gelatin solution is followed by a slight rise of the blood-pressure, which soon falls to normal. The coagulant action of the gelatin would appear to be much accelerated by the addition of calcium chlorid by mouth, but preferably in the Carnot solution (2 centigrams to 100 grams of a 3 per cent. gelatin and sodium chlorid solution), or by prescribing a 3 per cent. gelatin solution made with Locke's fluid, which contains enough calcium chlorid for the purpose. (See Calcium Chlorid in section on Hemorrhage.) Boinet and Vedeler advise the administration of gelatin, 10 per cent. in 0.7 per cent. of salt solution by enema, conjointly with the administration of the gelatin by mouth or by hypodermoclysis. The mode of action of gelatin is obscure; it is not transformed into peptone, it acts not by its acidity, as claimed by some, but by increasing the plasmase or fibrin ferment contents of the leukocytes or by a certain degree of leukolysis. Gelatin injections are usually absorbed in twenty-four hours; they cause no abscesses when prepared with proper and rigorous methods of sterilization (see Sterilization Method, section on Hemorrhage), and their value appears to be established by the great number of cases of reported improvement in favorable cases. The pains and pressure signs are moderated after the sixth injection; the aneurism hardens perceptibly after the tenth; complete hardening with arrested pulsation may follow after thirty or forty injections. When the treatment is followed by favorable results, it should be renewed and another series of injections repeated. However, cases of embolism and thrombosis have been recorded by several observers. Tetanus is probably the most serious danger to be apprehended from defective or imperfect sterilization. By subjecting the solution to a temperature of 110° C. for thirty minutes this danger can always be avoided

(Roux). To obviate all risk, ichthyocol, which contains 86 to 93 per cent. pure gelatin (obtained from the air-bladder of the sturgeon), has been applied with even more marked effect than the ordinary gelatin (Boinet, Huon).

My own experience with gelatin injections confirms the opinion that gelatin is not to be relied upon as a certain remedy, but the relief it furnishes in a considerable percentage of these unfortunate cases fully justifies its systematic administration in all inoperable aneurisms. It is especially indicated in sacciform aneurisms. A certain tendency to irritation of the kidneys in the course of its elimination, which would aggravate a coincident nephritis, is the only contra-indication.

Symptomatic treatment is called for to meet special indications. When external rupture is present, venesection was formerly recommended, but rest, with veratrum viride, will accomplish the same result without spoliation. Ice-bags over the well-protected skin may be used when the skin is inflamed, red, and glossy. When sloughing is threatened, ice will aggravate the condition, and compresses of lead-and-opium lotion should be substituted. Sachets made of sterilized gauze filled with the Indian fern—Pendjwar Djambi—or with hemostatic agaricus (punk) are especially valuable in staying the threatened hemorrhage. Absolute rest with low or milk diet is absolutely mandatory. Hypodermics of morphin and atropin with aspirin (Nunneley) are especially indicated for the relief of pain in conjunction with potassium iodid. Morphin, codein, heroin, dionin are also the best remedies for the warning hemoptysis which precedes the fatal rupture. Morphin also moderates reflex, spasmodic, and irritative cough. Extensive erosions of the vertebral column call for rest in bed or support with orthopedic corsets. Intubation is indicated for edema or spasm of the glottis; tracheotomy may be necessary from the start, with a long soft cannula, to extend if possible beyond the level of the tracheal compression. In conclusion, we believe with Boinet that the best and most opportune time to treat the aneurismal condition effectually is in the incipient stages of dilatation and arteriosclerosis, when vascular depressants, hygienic care, rest, the iodids, and gelatin will have an opportunity to act on comparatively healthy and resisting tissues, *preventing* the otherwise hopeless development of fully formed aortic aneurisms.

Surgical Treatment.—All external measures, applied directly to the aneurism, are included in this category. These include: *Refrigeration, compression, acupuncture, filipuncture, electropuncture.* These methods are only semisurgical or quasimedical as long as they do not include the open sections of the tissues in order to approach the aneurism directly. The strictly speaking surgical methods, apart from the above, are the classic operations, the *ligature,* in its various applications, above and below the sac; the occlusion of the parent artery by constricting appliances; gradual occlusion; Halsted's bands; gradual compression with graded clamps; elastic ligatures; Keen's compressor; the *radical* operations, by incision of the sac, aneurismotomy (Antyllus' operation); extirpation of the sac, aneuris-

mectomy (Philagrius' or Purmann's operations), with their later modifications.

Refrigeration.—At present ice is applied as a palliative in diminishing inflammatory congestion and as an adjunct to other treatment in inoperable aneurisms (gelatin treatment), and as a palliative it undoubtedly deserves a place in the treatment of this disease.

Aseptic acupuncture (needling), practised by Macewen (1890) for inoperable aneurism, consists in the introduction of a long needle into the aneurismal tumor, where it remains twenty-four hours, during which the needle is moved sufficiently to scratch the intima and produce sufficient irritation to induce the formation of white or plate-leukocyte-fibrin thrombi. Ciniselli in 1891 reported 33 cases with 7 deaths; favorable cases were reported in addition to those of Macewen, by Weir, Emmett (1892), Béguin, Bäumler. The method, however, is practically abandoned on account of its uncertainty, the difficulty of limiting the effect of the puncture to the internal surfaces, and the fact that the aneurism is already lined with laminated clot.

Wiring (Filipuncture), Moore's Method (1864).—Moore inserted and left a fine silver thread in a thoracic aneurism in order to induce clot formation from it. The length of the iron, steel, or copper wire thus employed has sometimes been considerable—from 33 to 100 and even over 200 feet. Later, silk ligature threads, catgut, horsehair have been successfully employed. Abbé left 100 feet of catgut and 150 feet of steel wire in an aneurismal sac. Of 34 known cases of thoracic and abdominal aneurisms treated by wiring alone, 30 died in the course of the year (Boinet, 1907).

Bacelli and Montenovessi (1877) introduced and left in the aneurism a number of fine metal watch-springs, the total length of which varied between 10 to 40 cm. Their first attempts were almost disastrous from perforation of the sac and other causes. The springs have been gilded in order to avoid oxidation and breaking, roughened by exposing them to the fumes of osmic acid, or dipped into hydrochloric acid or iron perchlorid. Migration of the wires, threads, and watch-springs is not infrequent, the stiffer wires finding their way into the aorta, even where the aneurism is saccular and provided with a narrow orifice of communication. In several cases the wires found their way into the left ventricle of the heart (Ballance, Parham).

Filigalvanopuncture.—The Moore-Corradi Method.—Corradi (1879), like Moore, introduced into an aneurism 40 cm. of wire, and then connected the extremity with the positive pole of a battery, the negative being applied in the vicinity of the aneurism. He failed, and so did his immediate followers. Hunner (of Baltimore), in a careful study and compilation of the reported cases treated by this method, up to 1900, combining the statistics of the thoracic and abdominal cases, collected 14 cases in which Moore's method of wiring alone had been adopted. Of these 14 cases, 8 were thoracic and 6 were abdominal. Two only of the abdominal cases were apparently cured (14 per cent. recoveries). With the combined method (Moore-Corradi), there are

23 cases, 17 thoracic and 6 abdominal. Four of these, or 17 per cent., recovered, including 3 thoracic (Rosenstein, Stewart, Kern) and 1 abdominal (Noble). By combining Hunner's statistics with my own, in 1900, I was able to collect 41 cases of aortic aneurisms (thoracic and abdominal), treated by wiring and wiring combined with electrolysis, with a total of 8 apparent recoveries (2 abdominal and 6 thoracic), or 19.20 per cent. recoveries. In 39 per cent. of Hunner's cases there was an apparent amelioration of symptoms and prolongation of life. "We must not be too sanguine on this improvement, for in any given case we cannot prophesy as to the patient's length of days or suffering if there be no operative interference." Without condemning the practice of wiring aneurisms as severely as Huchard, I must conclude now, as I did in 1900, that the uncertainties of this method, its dangers from migration of wire, from rupture and perforation of the sac, from thrombosis of the main artery and gangrene of peripheral parts, embolism from migratory emboli, all contribute to give this procedure the character of a pure experiment which is justified solely by the imminent and unavoidable danger of death from the progress of the disease itself.

Since Corradi introduced the combined method in 1879, great improvements in the technic have been made, especially by American and British surgeons, who have applied this treatment more often than those of other countries. The chief improvements lie in the better wire, highly drawn, fine, snarled, silver wire, not to exceed No. 28 gage (0.0085 inch) in diameter. Gold wire is used by Stewart; silver blended with copper alloy (Finney, Hunner), the length not to exceed 10 feet, allowing a current not to exceed 70 milliampéres (I have used 200 milliampéres without appreciable bad effects). The open method of approaching an aneurism and isolating it in the abdominal cavity after laparotomy, to facilitate inspection and avoid sepsis during the treatment (by packing or coffer-damming the sac) (Parham), by suturing the parietal peritoneum to the peritoneal sac (Matas), are also improvements in the technic of the abdominal cases. D'Arcy Power (1903) improved the technic by utilizing an apparatus devised by G. H. Colt. This consists in a closely packed wire, which is twisted through a fine cannula previously introduced into the sac, where it expands, thereby insuring a better distribution of the wire network and reducing very greatly the time required to insert many inches of wire.

Mediate Galvanization.—Galazzi and Vizzioli applied a positive constant current of 50 to 60 milliampéres to the external surface of the aneurismal tumor and a negative pole to the surroundings. Each session lasts fifteen minutes, and is repeated every other day. Of twelve small aneurisms of the thoracic aorta treated in this manner, 2 cases were almost cured, 6 were improved, 4 remained stationary. Britto (1904) recommends positive cutaneous voltaization for the treatment of aneurism. The advantage of these methods is the simplicity of their application. They appeal to us more as placebos than as real remedies.

Compression.—In the preantiseptic period, when all operations involved serious risk, mediate or indirect compression was regarded as the method of election in the treatment of aneurism. The object of pressure is to bring about consolidation of the aneurism by the formation of either a laminated or an ordinary coagulum. The methods of bringing this about may be considered under: (1) Direct pressure on the aneurism; (2) indirect or direct pressure, either on the artery above or the artery below, or on both simultaneously.

Direct pressure over an aneurism limited to its surface is now never practised. Efforts to control the growth of a thoracic or abdominal aneurism by compression have proved disastrous, being followed by embolism or by rupture into the internal cavities of the body.

Indirect Pressure.—Compression of the artery above the aneurism was first applied in 1784 by Desault, who was likewise the forerunner of John Hunter in the ligation of the artery above and at a distance from the sac. It was not frequently adopted, however, until 1844, when it was brought more prominently to professional attention by Billingham and the Dublin surgeons, and by the great authority of Broca in France, who warmly advocated it in 1863. It is applied to the artery above, the artery below, or to both at the same time. In either case its object is to promote the coagulation of the sac contents. Its mode of application may be classified into: (*a*) Digital pressure; (*b*) instrumental compression; (*c*) elastic compression; (*d*) compression by flexion.

Digital compression was first applied as the sole mode of treatment by Jonathan Knight (1844), of New Haven, Conn. In France it is known as the method of Belmas. Knight's case was one of popliteal aneurism, and a cure was effected in about two days. It is of all the bloodless methods of compression the simplest, the best regulated, and probably most efficient. Digital pressure cannot be made satisfactorily without the aid of a considerable number of assistants, hence its application is limited to hospital practice. It is usual to employ the assistants in pairs, one making pressure while the other feels for pulsation in the sac. "The skin should be covered with French chalk at the point where the pressure is made, and the assistants should be carefully instructed as to the amount of pressure needed and the place where, and direction in which, it should be made upon the main trunk. When the change is made from one assistant to another, the latter should place his finger or thumb upon the artery immediately above or below that of the one whom he replaces, and this one should not remove his finger until after the artery is duly compressed by the other. Ether or morphin should be used when the patient begins to complain of pain" (Stimson).

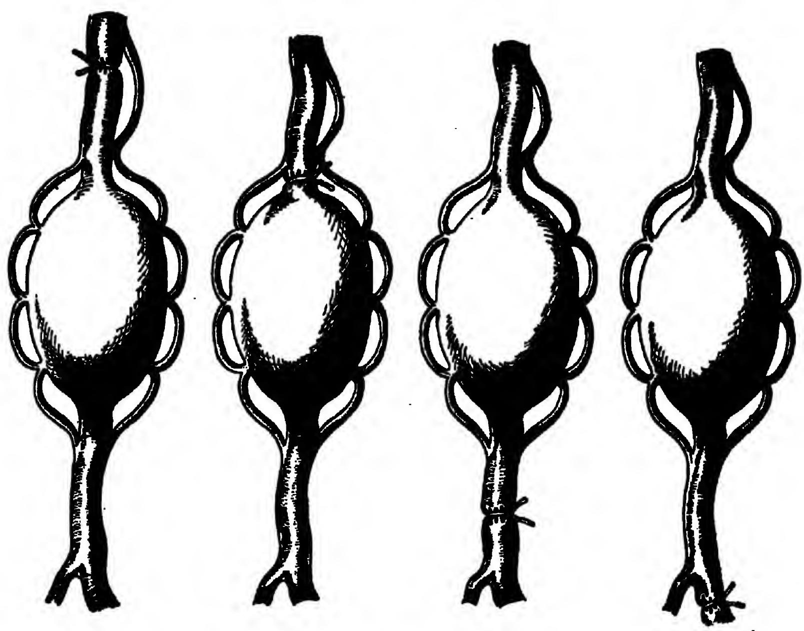
The conditions most favorable for digital pressure are found over the femoral, just below the groin, where the pubic arch forms a solid resisting plane. It has been applied almost exclusively for the cure of popliteal aneurisms. Constant complete compression, so as totally to arrest the pulsation in the sac, is alone effective. Each sitting should

last four hours. It is important to change the point of compression on the artery for fear, in arteriosclerotic individuals, of producing injury to the skin or secondary aneurisms at the point of compression (Berger, Annandale). Aside from the inconvenience of applying this method except in hospital surroundings, where numerous assistants are available, it is also uncertain in its duration. According to Fischer, in 90 cases treated by this method, 72 were completely cured. Of these 72 successful cases, 19 were cured in from one to twenty hours, sometimes in the first sitting; 7, from twelve to twenty-four hours; 6, from twenty-four to thirty-six hours. For the remaining 40, ten sittings in as many days were required. According to Delbet, the chances of cure diminish progressively after the first ten sittings. After thirty-six hours the chances of cure become very small, the dangers of the treatment are greatly increased, and it is best to abandon it. Apart from the great inconvenience of its application it predisposes to gangrene of the extremities. Especially is this dreaded complication liable to occur if the stream of blood in the aneurism is frequently interrupted by unsteady application of the digital pressure. In 96 cases there were 76 recoveries and 8 deaths; 6 of these deaths occurred after subsequent ligation, the remaining 2 after amputation. Gangrene occurs in 6 per cent. Recovery may be expected in only 50 per cent.

Instrumental pressure, either proximal or distal to the aneurism, may be applied with a variety of instruments which have been invented for this purpose. They have been applied chiefly in the treatment of abdominal aortic aneurism. Woirhaye reported 6 recoveries out of 9 cases operated on; as usual, the unfavorable cases are not reported. General anesthesia is indicated, and the compression applied at an equal distance from the xiphoid process and the umbilicus, until the pulsation disappears in the tumor and in the femoral arteries. It is applicable only in a few especially favorable cases, in thin subjects, and when the aneurism is situated very low, near or at the bifurcation. Notwithstanding the recovery of the few cases recorded, it is now practically abandoned, since it is fraught with great risk from gangrene of the intestines, embolism and thrombosis of the peripheral arteries, rupture of the atheromatous aorta. It is advisable not to compress the aorta for more than an hour at a time, if it is resorted to at all.

Elastic Compression, Reid's Method (In Italy, the Reid-Clementi Method).—This method was first applied by W. Reid, of Plymouth, England, in 1875. The object of the method is simultaneously to compress the artery above and below the aneurism, thus causing the blood contained in both the aneurism and the artery to coagulate. The elastic bandage, in cases of popliteal aneurism, in which it has been most often used, should be evenly applied from the foot as far as the aneurism, a turn should then be made over the tumor, so as only lightly, if at all, to compress the sac, and the bandaging then continued firmly half way up the thigh. The bandage should be kept on for an hour to an hour and a half. The elastic *cord* should not be used at all. On removing the bandage, digital or instrumental pressure should

be kept up on the main artery from thirty-six to forty-eight hours, so as to control the circulation and prevent the clot, which is still soft, from being washed out of the artery and the sac. The patient should be placed under an anesthetic during the application of the bandage, as it causes great pain (Walsham). In 1881 Stimson collected 62 cases treated by this method. In 52 cases in which Reid's method was applied without modifications, there were 28 cures, 22 failures, and 2 deaths. Of the cures, 24 were obtained by a single attempt continued for about an hour; on the average, the extremes of time varying from fifty minutes to three and a half hours. He estimates that Reid's method may be expected to fail in at least 15 per cent. of the cases, a



1 2 3 4

FIG. 77.—VARIOUS METHODS OF LIGATION.
1, Hunter's ligation, proximal; 2, Anel's ligation, proximal; 3, Brasdor's ligation, distal, of trunk; 4, Wardrop's ligation, distal, of branch of trunk.

very favorable estimate, judging by Delbet's statistics. Reid's technic has been modified by many operators. Gersuny never exceeds half an hour at a sitting and multiplies the sittings. This method is known as elastic intermittent compression (Petit). Reid's method enjoyed great favor at one time, but it is now seldom practised. Delbet's statistics (1889) showed 48.2 per cent. cures. It leads to gangrene of the limb twice as often as digital compression (Delbet).

Flexion, known incorrectly as *Hart's method*. This was apparently first suggested by Ellsworth (1844) and Fleury, a French surgeon (1846), afterward used by Thierry, Maunoir (Geneva), and Hart in 1857. Flexion has been tried successfully in the treatment of popliteal aneurism and aneurism of the groin and the elbow. In applying it, the pulsation

in the peripheral vessels beyond the aneurism must be arrested. Flexion accomplishes a cure in 35.55 per cent. of the cases. It is apparently a simple measure, but it is long and painful, averaging fourteen days before coagulation can be obtained even in the most favorable cases. It leads to prolonged stiffness in the joints, and, what is worse, according to Delbet, it leads to the rupture of the sac eight times more often than digital or other methods of indirect compression.

The Ligature.—A ligature is applied to an artery in the cure of aneurism for the purpose of arresting or retarding the circulation in the aneurismal sac and thus favoring its obliteration by the rapid or gradual coagulation of its contents. To accomplish this object, the ligature may be applied to the artery at different points in relation to the aneurism. It may be applied on the (1) *proximal side*, immediately above the sac, and is then known as Anel's operation (Fig. 77, 2), after the first surgeon who treated aneurism by the ligature in 1710. It may be applied at a distance from the sac—for example, in Hunter's canal, in treating popliteal aneurism—when it is known as the Hunterian operation, after John Hunter, who ligated the artery at this point (Hunter's canal) December 12, 1785; Désault had previously ligated the femoral for popliteal aneurism at or about the same level (immediately below the opening of the abductor magnus), June 22, 1785, both operators ligating at a distance to avoid the supposedly more diseased arteries in the vicinity of the sac. Or it may be ligated at a still higher point on the same principle in Scarpa's triangle (Scarpa's operation), as it was done by A. Scarpa, at a much later period (1819). (2) The ligature may be applied on the *distal side* very close to the tumor; it is then Brasdor's operation (1798—Fig. 77, 3); or to one or two of its main branches, Wardrop's operation (1825—Fig. 77, 4). In the aneurisms of the innominate artery, if the ligature is applied to the subclavian above it, it is Brasdor's operation that is performed; if applied to both the subclavian and the carotid of the same side, it is Wardrop's operation. (3) Immediately above and below the aneurism without opening the sac (Pasquin's operation). If the sac is opened, it is the operation of Antyllus. All ligatures applied on the proximal side, when these are at a distance from the sac, are usually referred to as Hunterian operations.

FIG. 78.—LIGATURE OF THE SUPERFICIAL FEMORAL ARTERY FOR POPLITEAL ANEURISM BY MILONI. (Ballance and Edmunds, after Porta.)

The *distal ligature*, Brasdor and Wardrop's method, first suggested

by Brasdor and Désault toward the end of the eighteenth century, was first performed by Deschamps in 1798 and by Sir Astley Cooper. In 1825 Wardrop obtained the first success from this method by tying the common carotid on the distal side of a large aneurism. The operation is now practically restricted to aneurisms of the common carotid, subclavian, and innominate, in which the proximal ligature or other and more valuable methods of treatment are impracticable. It is an uncertain method at best, but since the aseptic epoch the mere ligation of arteries as an operative procedure has been made so simple and comparatively safe that it is justifiable and is done with the view to favoring the deposition of the clot in the sac, if only as a palliative method.

The *double ligature* above and below the sac without disturbing it: without incision of the sac. This method, which has been most fre-

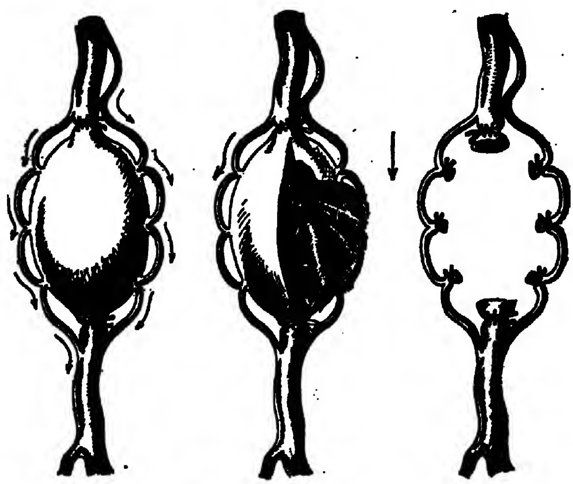


FIG. 79.—1, Double (bipolar) ligation of the parent trunk on the proximal and distal side of the aneurism (Pasquin's method), showing how the sac can still be nourished by the collaterals; 2, the operation of Antyllus—bipolar ligation of the parent trunk, with incision and packing of the sac (showing how primary and secondary hemorrhage may occur in this procedure from the abundant collateral supply); 3, the radical operation by the extirpation of the sac (Philagrius' or Purmann's operation), showing how the collateral circulation is maintained and how it is possible to interfere with it seriously by the ligation of the branches given off from the aneurism (see the collaterals on the left side of the diagram).

quently applied to the treatment of arteriovenous aneurism, is not applicable with any advantage to simple arterial aneurisms. According to Broca, it was applied by Pasquin in 1812 (Fig. 79, 1). It has never met with favor as a surgical method, because all that can be accomplished by it can be done with greater advantage by other more certain and complete methods.

The Proximal Ligature at a Distance from the Sac, or Hunterian Ligature.—This operation was until quite recently the preferred method of treating aneurisms. The chief merits claimed for it are (Walsham): (1) That the artery at the spot selected for the ligature is not only more likely to be healthy, but is also more easily tied than the artery

in close proximity to the sac, in which latter situation, moreover, its anatomic relations are liable to be disturbed by the aneurism; (2) that the sac is not interfered with, and hence is less likely to become inflamed and suppurate than by close ligature to the sac; and (3) that, as several branches will probably be given off between the ligature and the aneurism, the circulation through the sac, though lessened, will not be completely arrested, and the clot is, therefore, more likely to have a laminated and hence a permanent character.

Objections to, and Disadvantages of, the Hunterian and other Methods of Proximal Ligation.—Since the advent of the aseptic period, and the general adoption of modern methods of ligating arteries, the disadvantages of the Hunterian ligature have become more apparent, and the once almost forgotten method of Anel has come to take its place. The chief objections formerly raised against the ligation of the parent artery close to the sac have been removed, as far as the method of ligation is concerned, and its superiority over other ligatures in favoring the permanent obliteration of the sac, with much less danger to the collateral circulation, has made it preferable whenever the treatment of aneurisms by proximal ligation is indicated or adopted by the surgeon. The disadvantages of the Hunterian ligature may be summed up as follows: (1) The liability to gangrene of the limb is increased by (*a*) the interposition of two obstacles to the path of the blood from the cardiac side to the periphery; first, at the seat of the ligature, and, secondly, at the site of the aneurism, which is totally or partially blocked by clots after the ligation; (*b*) by putting out of function a large number of important and often essential collateral branches given off from the main trunk between the ligature and the aneurism; in some cases the track of the artery becoming obstructed by a thrombus for a great part of its length after the ligation; (*c*) in consequence the blood has to pass through two sets of collaterals before it can reach the part beyond the sac; (*d*) the risk of gangrene, therefore, increases in direct ratio with the distance interposed between the sac and the ligature; (*e*) the risk of obstruction of the distal end of the artery beyond the sac by emboli or propagated thrombi is greatest in the Hunterian ligature, which aims at the gradual and not immediate suppression of the circulation in the sac, the minor circulation in the sac resulting from previous collaterals which empty into the main trunk above the sac, favoring the increased deposition of active clot, and also breaking up the new soft and passive clot formed temporarily by the ligation of the main trunk. (2) The reëstablishment of the collateral circulation after ligation at a distance may carry more blood into the main artery (between the ligature and the sac), and thus lead to relapse. (3) There is no advantage in ligating the artery at a distance, because (*a*) the simple aseptic ligature strengthens the artery at the seat of ligation, and there is no secondary hemorrhage when there is no suppuration; (*b*) it has been shown that the arteries are often quite healthy immediately above the aneurism (especially in traumatic cases); and (*c*) it has been also shown that arteriosclerotic arteries undergoing gradual obstructive changes are as

readily closed by aseptic ligatures as the healthy ones. (4) The ligature at a distance, by allowing the persistence of a modified (lessened) circulation in the sac, favors the further deposition of fibrin, and thereby the sac remains larger than when the immediate proximal ligature (Anel) is applied, because this shuts off the circulation at once and allows draining of its fluid contents, also allowing the old laminated clot to remain; thus, the volume and size of the sac is less, and the tendency of the passive clot to break up is also lessened. (5) The danger of infecting the sac by the manipulations required to ligate the artery at its termination in the sac is not to be considered in aseptic operations.

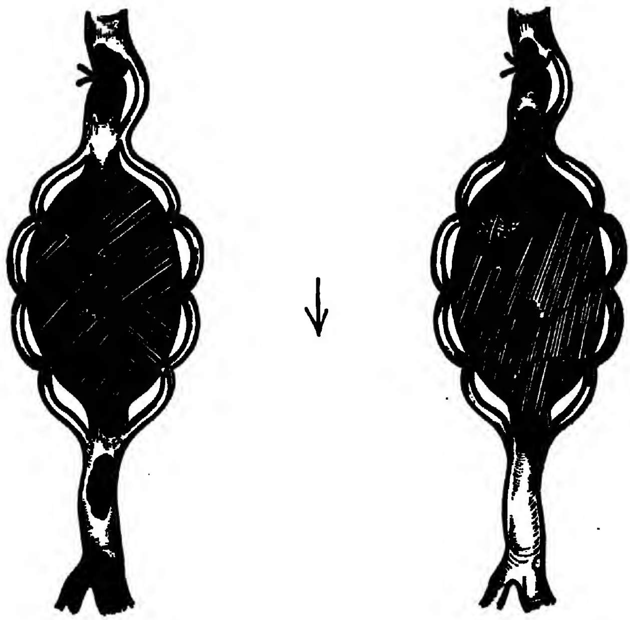


FIG. 80.—1, Diagram showing how peripheral gangrene may occur after a proximal ligation; masses of clots (emboli) are detached from the aneurismal cavity and block up the distal trunk at its bifurcation. In popliteal aneurism the anterior and posterior tibial may be thus blocked up simultaneously with fatal effects; 2, after the Hunterian ligation especially, the openings of important collaterals may be obliterated by thrombi or emboli between the ligature and the opening of the aneurism. A third mode of interfering with the *collateral* supply is shown in 2. The orifices of the collaterals inside of the sac and the vessels themselves may be plugged by extension of the thrombotic process into their lumina.

Therefore it is evident that proximal ligation as near the sac as possible is to be regarded as the preferred method of ligation. Instead of ligating at Scarpa's triangle or Hunter's canal for popliteal aneurism, the ligation should be made in the popliteal space. Veneration for Hunter's memory, its simplicity, and the traditional regard for authority, gave the Hunterian ligature the first rank, not only in preference to the Anel method, but to all methods of treating aneurisms, long after its relative inferiority as a method of treating aneurism had been established. It is only the indisputable evidence and success of other methods obtained since the aseptic period that has

led to its very gradual and reluctant displacement in surgical esteem in English-speaking countries. However, the introduction of the proximal ligature for the cure of aneurism was an immense stride forward in the treatment of aneurism.

We have already noted the fact that digital compression, the best of the indirect and bloodless methods of compression, yielded only 50 per cent. of cures. Now Delbet, who, as the chief advocate of extirpation, has most assiduously scanned the statistics of ligation with the superiority of extirpation in view, admits that the ligature in the modern period accomplishes an apparent cure of the aneurism in all but 5 per cent. of the cases, the failures being due to gangrene or relapse. As to the mortality, which was very high in the pre-antiseptic period, it has remarkably changed for the better with the modern period. In 1874 Holmes' statistics gave 13 deaths in 87 cases of popliteal aneurism treated by the ligature, a mortality of nearly 15 per cent., say one in seven (Stimson). In 1888 Delbet found the mortality to be 18.94 per cent., while in 1895 it had been reduced to only 8.35 per cent. Gangrene, however, still remains a serious objection to *all* methods of ligation. Delbet's statistics give a proportion of 7.58 per cent. in 1888 and 8.25 per cent. in 1895. Aseptic methods, while greatly reducing the mortality, have exercised very little if any influence upon the occurrence of gangrene. The reason for the persistence of this disastrous complication in spite of the aseptic technic is well expressed by Delbet, who first pointed out that gangrene is not due simply to the insufficiency of peripheral circulation, but to the frequent displacement of clots (ebolic) from the sac into the distal portion of the artery and its branches after the sudden arrest of the circulation.

Gangrene is, therefore, the chief objection to any method of ligation on the proximal side, though less likely to occur in the Anel than in the Hunterian operation. This is most apparent in the treatment of popliteal aneurisms in which (42 cases) there were 87.50 per cent. of recovéries and 12.95 per cent. of failures. Of the recoveries, 8 were imperfectly cured (persistent tumor, functional disability, etc.), 10.50 per cent. had gangrene of the toes, and 3 out of the 5 failures had gangrene requiring amputation of the leg. In addition, 4.60 per cent. of the cases of ligation relapsed and other methods of treatment had to be resorted to.

The sac, which remains full and indurated after the ligation, usually contracts after it has been filled with clot. The bulk of the clot is removed by absorption, degeneration, and phagocytosis, leaving a small residue to organize and remain as a pseudomembranous formation. Not infrequently the laminated clot remains in bulk, undergoing organization, acting as a foreign body interfering with the venous and lymphatic circulation, as shown by a persistent edema. Sometimes it becomes infected, suppurates, and ruptures. After apparent consolidation, a period of latency sometimes lasting seven years (Hawkins), ten years (Smyth), fifteen years (Cooper), the sac becomes active

again, requiring other operations to control it. Sometimes a new aneurism follows at the seat of the ligature. In 1895, Delbet gathered 6 cases of this kind, and I have added fully 8 from the recent literature. (See Influence of Traumatism in Pathogenesis.) When the sac remains undisturbed the adherent and overstretched nerves continue to undergo nutritive changes, a sclerogenic interstitial pressure-neuritis, which are initiated during the life of the aneurism. In this way neuralgias, trophic ulcers, paresthesias, motor disturbances in the peripheral part, continue to remain unrelieved after the operation. From what has been said it is evident that, while the methods of ligation for the cure of aneurism have rendered great service in the cure of this disease, there are serious defects and dangers inherent to *all* methods which leave the sac *undisturbed* and filled with *clot*—objections which remain. To avoid these and still further improve the results, especially as regards the incidence of peripheral gangrene, is the aim of modern surgery, and it is in this direction that the greatest advances have been made and are now in process of development.

Partial occlusion and gradual obliteration of arteries was discussed by L. Porta (1800–1875) about the middle of the last century, and gradual occlusion by instruments carrying a snare or by instrumental compression immediately or mediately, by elastic ligature, or by a series of gradually contracting ligatures, has been repeatedly tried and advocated in the treatment of aneurisms in which it was feared that the immediate occlusion of the artery by ligature might lead to ulceration and secondary hemorrhage or to gangrene.

As an advanced step in this direction, Halsted, of Baltimore, has evolved the valuable method of gradual occlusion of the large arteries with metal bands (Fig. 81). He prefers an aluminum metal band, the width of one-third or one-half of the lumen of the vessel to be obliterated; the thickness of the bands is from 29 to 36 sheet-metal gage. The band is rolled around the artery with a special instrument and the final tightening of the band is accomplished with the fingers. The procedure has been tried in over 100 dogs, chiefly on the abdominal aorta. One dog has survived a complete occlusion of the thoracic aorta brought about gradually. When there is complete occlusion of the aorta, and even when not quite complete, paraplegia is observed, and in the smaller dogs soon was followed by death. In the survivors, the paralysis diminished greatly in three to ten days. The paraplegia is associated with a rapid deposition of extradural fat in the spinal canal, sometimes compressing the cord (Gilman). The effect of occlusion on the arterial pressure above the band was not stuided

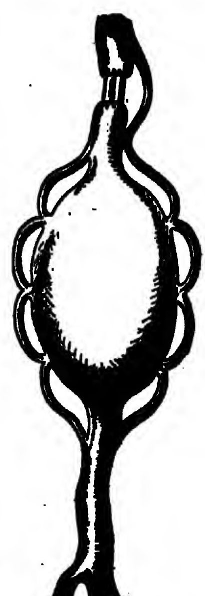


FIG. 81.—HALSTED'S METHOD OF GRADUAL OCCLUSION WITH METALLIC BANDS.

instrumentally by kymographic tracings, but it is estimated that the pressure below the band is diminished in proportion to the amount of occlusion. Partial occluding bands produced, as a rule, no visible changes in the arterial walls, even after seven or eight months. Under completely occluding bands the wall usually atrophies, to the extent, sometimes, of complete absorption of the aortic wall. Hemorrhage in such cases has been prevented by the formation of enveloping connective tissue. The dangers to be apprehended by this method—pressure atrophy, with ulceration and hemorrhage above the band, embolism or thrombosis—do not figure to an appreciable extent in the experimental mortality. Only one dog died in the entire series of experiments from hemorrhage caused by pressure ulceration above the ring. Complete thrombosis has never been observed. When the lumen is almost or quite occluded, complete occlusion may result spontaneously, with the conversion of the arterial wall embraced by the band into a solid cylinder of living tissue.

Practical applications of this method, as stated by Halsted and his assistant, Sowers, are: (1) In cases of aneurism where ligation is attended with danger of gangrene. (2) In the case of ligature of the common or internal carotid, the occlusion may be produced gradually; and subsequently, should cerebral symptoms develop, the band may be removed. (3) In aortic aneurisms, partial and progressive occlusion of the aorta can be obtained by this method. (4) The band is possibly safer than the ligature for calcareous arteries. The bands have been applied to human subjects as follows: Thoracic aorta; the carotids, five times, to starve inoperable malignant disease; once on the innominate, for aneurism; once on the femoral, for popliteal aneurism; in all with apparently satisfactory results as far as the partial occlusion of the artery is concerned.

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The Radical Operations.

(I) Aneurismotomy (the Antyllian operation).
(II) Aneurismectomy (the operation of Philagrius and of Purmann).
(III) Endoaneurismorrhaphy and aneurismoplasty.
(IV) Aneurismectomy with (*a*) associated arteriorrhaphy; (*b*) associated angeioplasty (arterial and venous transplantations).

All these methods have several features in common; that is, they attack the aneurism directly; they limit the interruption of the circulation in the parent artery to the extent of the aneurismal area only when the main arterial channel cannot be restored; they all relieve the tension in the peri-aneurismal tissues by emptying the sac or by removing it with its contents. In these three important and fundamental particulars they are all superior to the methods of treatment previously described.

The two fundamental operations, aneurismotomy and ancurismectomy, are almost as old as the history of medicine, at least as old as the Christian era, and have been revived in actual practice only by the advance and accomplishments of the Listerian period; the other two operations, as fundamental procedures (endoaneurismorrhaphy, ancurismoplasty, and aneurismectomy with angeioplasty), have come into existence only in the last decade, and have been made possible solely by the conditions and progress of contemporary surgery.

For full and interesting information on the history of these procedures, see Broca, Traité des Anevrysmes, Paris, 1856; and A. Koehler, Beit. z. Geschichte der Extirpatio Aneurysmatis, Arch. f. klin. Chir., Bd. lxxxi., 1906.

Aneurismotomy.—The operation of Antyllus (Fig. 79, 2), as performed in the modern period, consists essentially in opening the aneurismal sac after securing the parent artery with ligatures above and below the sac; the operation is performed in the extremities with the protection of the Esmarch or other constrictor. The clot is evacuated and the constrictor or tourniquet is removed. If bleeding occurs in the sac from the mouths of the collaterals which open into its interior they are sought for and *ligated outside* of the sac. A probe or catheter, introduced from within the sac, is used, when possible, as a guide to secure the vessel outside of the sac (Annandale). After the hemorrhage has been arrested the sac is packed with aseptic gauze and allowed to heal by granulation. As described by Oribasius, the operation performed by Antyllus was always preceded by a dissection of the sac and a search for the afferent and efferent trunks, which were secured both above and below the sac before this was incised; after the introduction of the tourniquet the sac was often evacuated by free incision, the main vessel being secured after the aneurism had been emptied. Syme, in 1857, revived and modified the procedure, while operating upon carotid and subclavian aneurisms, in which the central end of the main artery was difficult to secure for prophylactic hemostasis, by making a small incision directly into the sac, just large enough to admit the index-finger. With the finger he searched the interior of the sac and located the afferent opening, plugged it with the fingers, and

then dissected the sac and ligated the main artery. While he was successful, few surgeons imitated his boldness, as the penalty paid for such temerity by the profuse and almost uncontrollable hemorrhage which followed from the distal end and from the collaterals was too great to justify it. Since the advent of asepsis the Antyllian operation has been performed more frequently, but the manifold objections to the procedure as classically performed led to its abandonment for the ligature and subsequently for the method of extirpation.

The *Mikulicz operation,* a modification of the Antyllian operation, was performed by von Mikulicz several times with success. Its chief object is to evacuate the contents of the sac, after the arrest of the circulation and consolidation of the sac have been obtained by ligature. The operation is divided into two stages: First, a ligature is applied to the main vessel on the Hunterian or Anel plan. After a variable time, when the arrest of the circulation in the sac has been

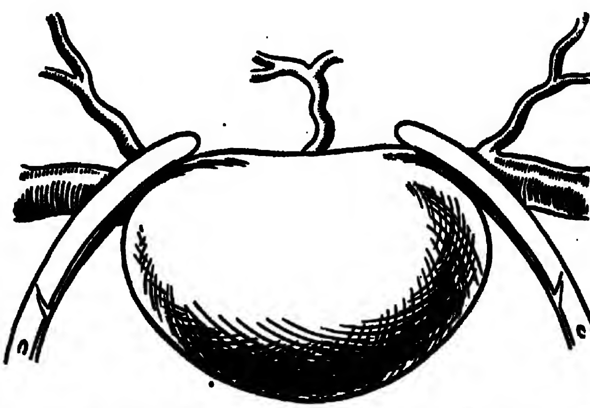


FIG. 82.—Provisional (preventive) hemostasis with soft elastic metal clamps in regions in which the circular elastic constriction of the limb is impracticable (neck, root of limbs, abdomen). Note that the clamps are applied as close to the sac as possible to control the large collaterals usually found at the poles in fusiform aneurism.

confirmed, the sac is opened by an incision not larger than is absolutely required for the evacuation of the coagula or by means of a puncture with a large trocar. This operation has no advantages over the proximal ligation or any of the radical operations, and is attended with greater risk than any of these, both from the possibility of secondary hemorrhage in the second stage and in not obviating the risk of gangrene. It has nothing to recommend it, in spite of the advocacy of Hoffman, except the prestige of the distinguished surgeon who first performed it.

Aneurismectomy, Extirpation; Philagrius' or Purmann's Operation.—To overcome the objections which have been urged against the Antyllian method, the old operation of aneurismectomy, known clinically as the operation of Philagrius or Purmann (who reinvented it in 1680), has been reintroduced. This operation, thanks to the efforts of Trélat and Polosson (1885), has become the accepted

operation of election on the continent of Europe. In England and English-speaking countries it has only recently found favor and with comparatively few surgeons, the Hunterian ligature still holding the first rank.

Extirpation is performed as follows: Prophylactic hemostasis must be obtained in the extremities by circular constriction at the root of the limbs; in the neck and other parts of the body, where circular constriction is impracticable, the main circulation of the aneurism must be controlled by a preliminary exposure of the afferent and efferent vessels, in order to guard against hemorrhage. In doing this, the vessel must be compressed as near the aneurism as possible; otherwise, very fierce hemorrhage may occur from branches given off between the ligature and the sac. Instead of ligatures, the vessel may be controlled by applying forceps or clamps (such as Crile's, Alleghiani's, Billroth's, Hoepfner's, or my own), which obliterate the lumen without damaging the intima (Fig. 82).

This preliminary control of the main vessel is absolutely necessary, if only to minimize the loss of blood on opening the sac, as in the vast majority of active aneurisms, especially those of the neck or at the root of limbs, numerous branches open into the sac, which invariably bleed vigorously and violently, even after the parent trunk has been well controlled on both sides of the sac. Thiel, for instance, in extirpating a recent aneurism of the femoral, in addition to ligating the external iliac artery above and the femoral artery above and below, had to ligate the external circumflex iliac, epigastric, profunda femoris, and also the vein accompanying the latter. In view of the difficulty of identifying the satellite vein when collapsed and embedded in the aneurismal sac, it may be advantageous to adopt Koehler's suggestion, with the aim of bringing the vein prominently into view if it is at all permeable. In popliteal aneurisms, for example, he applies a circular elastic constrictor below the aneurism (peripherad), about the level of the calf. The Esmarch bandage is then applied from this level up to the middle of the thigh, where the regular constriction is applied. After the removal of the Esmarch, complete ischemia is obtained throughout the seat of operation, leaving a reserve venous accumulation beyond the line of the first constrictor, which has been allowed to remain during the operation. If after exposing the sac there should be difficulty in deciding whether the vein has been obliterated or not, the lower (venous) constrictor is removed and the vein is allowed to fill up, thus showing where the vein is and whether it is permeable or not.

Koehler's expedient can be applied by leaving a circular elastic bandage at the desired level, the ischemia of the limb above it being obtained by elevation, gravity, and circular constriction. Ischemia without the Esmarch bandage should be preferred in all cases, but especially in the aged or markedly arteriosclerotic subjects.

A free incision is now made over the tumor down to the aponeurosis, when the dissection must proceed cautiously with a view to avoiding injury to the nerves and the veins, which are usually displaced and flattened out on the surface of the tumor. After the important nerves have been identified, the sac is detached from its surroundings by dry gauze dissection, unless the satellite vein is intimately adherent to the sac. Instead of enucleating or dissecting out the vein, it is safer to leave behind the part of the sac attached to it (Sonnenburg). All collateral ves-

sels entering the sac (sometimes very large and numerous) are exposed as the tumor is brought into view, and each one of these is ligated. It is best to preserve the sac without opening it until it has been entirely freed from its surroundings, removing it in this way like a cyst. Rupture and spilling of the contents usually occur in consequence of preexisting rupture or extreme thinness and adhesion of the sac at various points. Whenever the sac is found attached to important structures, the attached part of the sac should be allowed to remain. If the vein is accidentally injured, as is often the case, the rent should be closed with the finest silk or, if already obliterated, it may have to be extirpated. The extirpation or occlusion of the main vein is not to be regarded with indifference, as Kopfstein and his followers would lead us to believe. I believe that the preservation of the vein under these circumstances is a matter of decided importance to the vitality of the limb, and its sacrifice when unavoidable must always be a source of anxiety and apprehension. Finally, after the complete enucleation of the sac or, at least, as much of it as can be removed without injury to important parts, the artery is ligated at each pole and the tumor excised. After the removal of the constrictor all bleeding points should be ligated, so as to leave an absolutely dry wound. Otherwise a hematoma may form, requiring reopening of the wound.

It is important, for the same reason, or on account of previous infection requiring drainage, that no tight packs or tampons be employed, as the collateral circulation must not be interfered with by pressure of any kind. If possible, the wound should be closed without drainage. The deep wound is approximated with interrupted buried catgut sutures, the skin and overlying flaps with interrupted sutures. It is understood that the most rigorous asepsis must be maintained if primary union is to be obtained after extirpation, especially of extensive aneurisms. The manipulations and traumatism inflicted in dealing with old and irregular sacs in the femoral, axillary, or subclavian regions are sometimes very great even in the most skilful hands, especially in arteriosclerotic subjects. The dangers of infection and gangrene can only be avoided by the strictest modern aseptic technic.

Postoperative Treatment.—Although it is evident that postoperative gangrene, occurring as the result of insufficient vascular supply, can hardly be prevented by the after-treatment, be it ever so adequate, it still must be our endeavor to protect the extremity from circulatory disturbances by every available means at the operator's command, especially during the critical days following the operation. A cold skin and protracted postoperative cutaneous anesthesia are of evil omen, and may be the precursor of gangrene in two forms: (1) Total massive necrosis, starting at the digits and progressing centripetally up to the level of the block in the artery; or (2) necrosis in patches, involving the skin or underlying parts for a considerable depth, especially at pressure points—heel, malleoli, etc. To avoid pressure-necrosis,

copious dressings with non-absorbent cotton should be wrapped from the digits to the trunk, especially at pressure points, and the position of the limb should be changed at frequent intervals. Efforts to increase the arterial tension by drugs (digalen) when this is below normal, or by the infusion of physiologic salt solution by hypodermoclysis (6 to 12 pints daily, von Frisch), is indicated in order to favor the development of the collateral circulation; also artificial heat applied to the *entire* extremity and *moderate* elevation of the limb (to favor venous drainage). In cases in which the circulation does not return in the foot after two hours, the extremity remaining pallid and cold, the application of active hyperemia by Bier's hot-air apparatus or his suction apparatus may prove valuable, as von Frisch has suggested.

Permanent Effects.—The comparatively favorable results of extirpation, as far as the recovery of the patient and cure of the aneurism are concerned, are offset to a serious extent by the functional disability and local disturbances which persist long after the wound has healed and the patient has recovered from this operation. Even after apparently perfect recoveries, the extremity remains weak and shows little resistance to traumatism or exposure. These local disturbances, apart from actual gangrene, may be summed up as anesthesias, paresthesias, local hypothermia, edema, pain, and trophoneurotic disturbances, serious disorders of motility, which interfere with proper locomotion. These effects are not altogether due to trophoneurotic disturbances, as Delbet and Kopfstein contend, but to the insufficient reëstablishment of the collateral circulation, especially in old or arteriosclerotic subjects. To improve the nutrition of the limb and encourage the development of the circulation, hot-water baths, followed by gentle surface massage (effleurage), should begin early,—as early as the third week (von Frisch),—and should be kept up regularly for weeks and months. With the hot baths and massage should be combined active and passive movements of the joints, which remain stiff and often ankylosed. No effort should be made to use the limb in walking until the circulation is well established, and then only tentative exercises should be allowed. It is evident that a large number of cases reported cured after extirpation are only imperfectly cured, and remain unwell, with long-persisting functional disabilities.

Extirpation Compared with the Ligature and Other Methods.—Contrary to what is usually believed, the statistical results of extirpation, as far as the recovery of the patient and the limb is concerned, are less serious than the effects of the simple ligature, especially the Hunterian ligature. Delbet found in 1888 that the mortality of extirpation was 11.32 per cent., while that of the ligature was 18.94 per cent. In 1895 he made a new statistical compilation of 86 cases of extirpation without a death, and 8.33 per cent. of operative deaths after the ligature. As to gangrene, we find from Delbet's statistics that the ligature has been followed by gangrene in 7.65 per cent. of the cases from 1888–1895; 8.25 per cent. gangrene after extirpation; up to 1888, 2.94 per cent.; 1888–1895, 2.77 per cent.

If we compare this with the other operative methods as applied in the popliteal region (always a reliable basis for comparison), we find that the Hunterian ligature, 42 cases, gave 87.05 per cent. recoveries; 12.95 per cent. failures. Of the recoveries, 8 were imperfectly cured; 10.50 per cent. of these had gangrene of the toes, 3 of the failures from gangrene requiring amputation of the leg.

Relapses in Popliteal Cases.—According to Delbet, 4.50 per cent. of the ligated cases relapsed and other methods had to be resorted to. In 15 per cent. of the cases the operation failed to give complete relief, because of the persistence of the tumor, though not pulsating. Radical operation, same period, 32 cases. Extirpation (Philagrius), 19; incision and pack, 13. Results, no deaths; cure of aneurism in all.

Final Results.—In 10.40 per cent. of the cases of extirpation, superficial gangrene of the foot in patches, not requiring amputation, developed. In 8.33 per cent. of the cases operated by Antyllus' method gangrene followed, requiring amputation. While these statistics, as far as they go, clearly confirm the clinical *a priori* conclusion that either the simple incision of the sac or extirpation are safer for life and limb than the ligature, there still remain a very serious proportion of cases in which gangrene does occur. In 12 extirpations (8 popliteal, 3 femoral, 1 temporal, von Frisch) there were 5 gangrenes (41.6 per cent.), one of which compelled amputation of the leg, and another, a Lisfranc amputation of the foot (11.5 per cent.). According to Walsham (35 cases), gangrene, superficial and deep, follows in 10.3 per cent., which harmonizes remarkably well with Delbet's and von Frisch's experience. Very optimistically, Werner estimates the occurrence of gangrene after extirpation at 5.71 per cent. It is evident, therefore, that notwithstanding the enthusiasm of Delbet and his followers for this operation, the ideally safe operation has not been reached in extirpation.

Endo-aneurismorrhaphy (from the Greek *endo*, within; *aneurysma*, aneurism; *rhaphe*, suture).—The method of intrasaccular suture is referred to in the literature as the "Matas operation." This procedure I first applied on March 30, 1888, while operating upon a traumatic brachial aneurism which had resisted proximal and distal ligature. It was subsequently systematized as a method and carried out also in other cases of popliteal and femoral aneurisms which were reported to the American Surgical Association in 1902. In this paper the application of the intrasaccular method is divided into three types, to be applied according to special classes of cases: (1) *Obliterative* endo-aneurismorrhaphy. (2) *Restorative* endo-aneurismorrhaphy. (3) *Reconstructive* endo-aneurismorrhaphy or aneurismoplasty.

The intrasaccular method of suture, as the name implies, presupposes the existence of a complete or partially formed sac. In recent traumatic or false aneurisms (pulsating hematomas), too recent for the formation of an adventitious sac, the wounded vessels are recognized at the bottom of a raw, ill-defined, blood-filled space, without endothelial lining. In these conditions the wounded artery may be sutured by lateral or circular arteriorrhaphy, though this is not always possible; but should it be, such a procedure should be classed as a simple arteriorrhaphy,

as the former term (aneurismorrhaphy) implies that the suture has been carried through the sac-walls. Indeed, as elsewhere explained, there is a great difference between the delicate technic of arterial suture and that required to close arterial orifices in the sac of an aneurism or to restore the caliber of an artery opening into a well-formed sac. In this case it is much easier to close the gap by suturing the thick walls of the sac which lines the orifice of communication, etc., than to close an arterial wound without obliterating its lumen.

This difference between *aneurismorrhaphy* and *arteriorrhaphy* should not be overlooked in the discussion of the treatment of aneurism by suture methods.

The principles involved in this method are: (1) The aneurismal sac is to be regarded as a serous space. It is lined, in fully formed sacs, by an endothelial membrane of new formation, identical with the intima of the parent artery, from which it is derived by proliferation from its margins, and possibly also from the vasa vasorum; that as an extension of the vascular endothelium the intima of the sac, like other serous sacs, is possessed of the plastic regenerative qualities of the vascular and serous endothelia; that the sac is to be compared surgically to the intima of the blood-vessels, to the peritoneum, etc., and that as such it is not an inert membrane, to be regarded as a foreign and harmful body, as heretofore, but as a living and sensitive membrane capable of progressive, proliferative, and involutionary changes, which it will display—*if not detached from its vascular connections.* If the internal surfaces of the sac be brought together by suture, they will unite promptly and adhere by primary plastic union, like the serous surfaces of the peritoneum. Therefore, the arterial orifices in the sac will be readily obliterated by suture, hemostasis will be secured, and the sac cavity closed and excluded from the circulation. By leaving the sac undisturbed from its surroundings its nutrition will be preserved, no necrosis of the membrane will follow, and the sac will not act as a foreign body.

(2) That the disturbances and injury of the collateral vessels emanating from the sac and those lying in the immediate vicinity of the sac will be guarded against by intrasaccular suture as by no other method, and thus the liability to gangrene be diminished.

(3) That (*a*) if the parent artery is obliterated strictly within the internal boundaries of the sac by the intrasaccular suture of its orifices, and the intra-aneurismal orifices of the collateral vessels emanating from the sac are also closed by intrasaccular suture, the interruption in the continuity of the main channel as well as in the collaterals will be reduced to the strictest possible minimum; (*b*) in proper cases (sacciform aneurisms) the sac may be obliterated completely without interrupting the circulation in the main artery; (*c*) in certain cases (fusiform aneurisms) the parent artery may be reconstructed by creating a new blood-channel out of the sac-wall.

(4) That the collapse of the sac following a thorough removal of all detachable clot relieves not only the intra-aneurismal tension, but also that of the peri-aneurismal tissues (nerves, arteries, and veins), and gives the best possible opportunity for recovery from *pressure* effects, without the damage inflicted by the traumatism of extirpation.

(5) That the satellite vein, which is so frequently injured in extirpation, is spared when the intrasaccular operation is properly performed.

(6) That the sac can be obliterated and folded upon itself, so that primary union may be obtained and the wound closed without drainage, thus favoring a speedy convalescence, and obviating the long-protracted healing by granulation which was so objectionable in the old Antyllus operation. With these preliminary data in mind, the three different types of the intrasaccular method will be better understood:

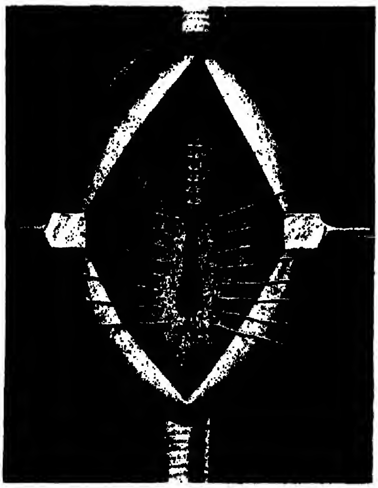


Fig. 83.—Obliterative Endo-aneurismorrhaphy. (Matas.)

Showing the orifices in the aneurismal sac in process of obliteration by suture when the restoration or reconstruction of the arterial channel is impracticable. The process of obliteration can be effected more quickly and thoroughly by the continued suture.

(I) **Obliterative endo-aneurismorrhaphy** (the fundamental procedure) consists essentially in opening the sac freely without disturbing it from its surroundings, by preliminary dissection, and closing all visible orifices within the sac with fine chromic gut or silk sutures, thus securing complete hemostasis and permanently stopping all further access of blood into the aneurismal cavity. The sac is obliterated in various ways, as will be explained, by approximating its walls with buried catgut sutures and closing the wound with or without drainage, according to the usual surgical indications. The distinctive feature of the procedure is that the continuity of the parent vessel is only interrupted for a length corresponding to the interval which separates the inlet and outlet of the aneurism as seen within the sac (Fig. 83).

The application of the obliterative procedure is indicated in: All aneurisms in which the sac is of the fusiform type, as defined in this article, and not as classically described—*i. e.*, in those aneurisms in which the parent artery is entirely lost at the site of the aneurism by expanding into the aneurismal sac throughout its circumference; also those in which the friability or diseased state of the sac-walls is such as to preclude all possible use as plastic material (atheroma, calcareous degeneration). In these cases there are always two orifices within the sac separated by variable intervals, and there is no visible outline of the main artery in the interior of the sac. Except in unusual conditions no attempt is made to restore the continuity of the parent artery; the blood-stream is interrupted in that part of the vessel which directly opens into the sac, and the arterial orifices are simply closed by suture, thus shutting off the sac cavity from all visible sources of blood supply.

(II) **Restorative Endo-aneurismorrhaphy.**—This variation in the procedure is solely applicable to aneurisms of the sacciform type, in which the parent trunk retains its continuity and normal outline, and the aneurism is a sac simply grafted upon the vessel. By opening the sac freely and washing out all detachable clot, the opening leading to the artery is exposed inside of the aneurism, and is readily closed by a continuous suture which penetrates through all the coats of the sac at the margins of the orifice of communication. By this procedure the blood-supply of the sac is permanently arrested, the lumen of the parent artery remains patulous, and the arterial stream supplying the limb or dependent territory is immediately restored through its normal channel. The sac is then obliterated by bringing its endothelial surfaces

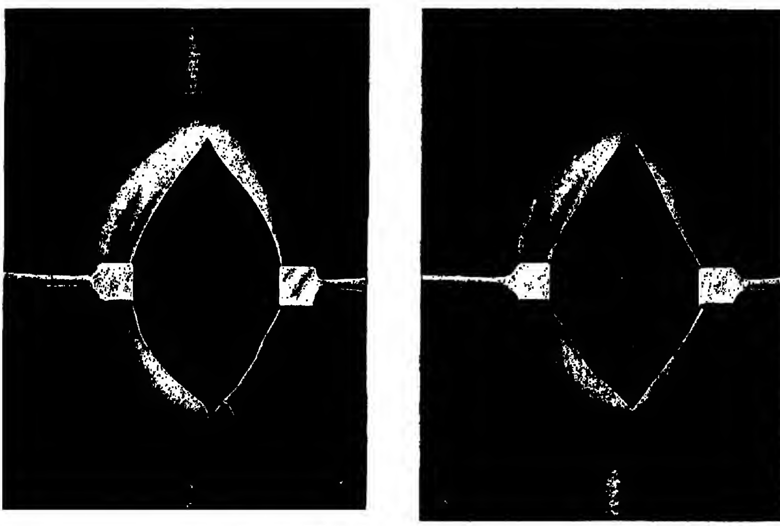


FIG. 84.—RESTORATIVE ENDO-ANEURISMORRHAPHY. (Matas.)

Applied to sacculated aneurisms with a single orifice of communication: A, Showing the process of obliteration of the orifice in the aneurismal sac without closing the lumen of the parent artery; B, the obliteration of the orifice completed.

together by infolding, or direct apposition with buried sutures, and the surface wound is closed in the usual manner.

This method is indicated, and should be applied as an obligate procedure in all sacciform aneurisms, as defined in this article, not only in those in which there is a single orifice of communication leading to the main vessel, but where there is a well-defined and deep furrow or gutter leading from the inlet to the outlet of the sac. This deep groove or fissure furnishes the outline of the parent artery, which is easily restored without obliterating the main channel (Fig. 84).

(III) **Reconstructive Endo-aneurismorrhaphy** (aneurismoplasty) is applicable solely to aneurisms of the fusiform type in which the walls of the sac are firm, elastic, and resistant; where the two openings leading to the main artery lie on the same level, in close proximity, and are situated at the bottom of a superficial or readily accessible sac. In

aneurisms of this type, especially those of traumatic origin, the continuity of the parent artery may be restored by making a new channel out of the sac-walls, which can be brought together by suture over a guide (catheter or drainage-tube) inserted into the proximal and distal openings of the aneurism. Before tying the last (middle) suture the guide is removed and the channel is left behind, corresponding to the outline of the original artery (Fig. 85). The sac is then obliterated by approximating its surfaces with fine buried chromic catgut sutures, as applied in the first and second procedures. The special indications for this type of the intrasaccular operation are still under consideration, and will be better defined in future after a larger experience has accumulated. In 1902, when my experience with the method was limited to 4 femoral cases, I felt that there were probably numerous cases of aneurism of the lower extremities, with edematous cyanotic and

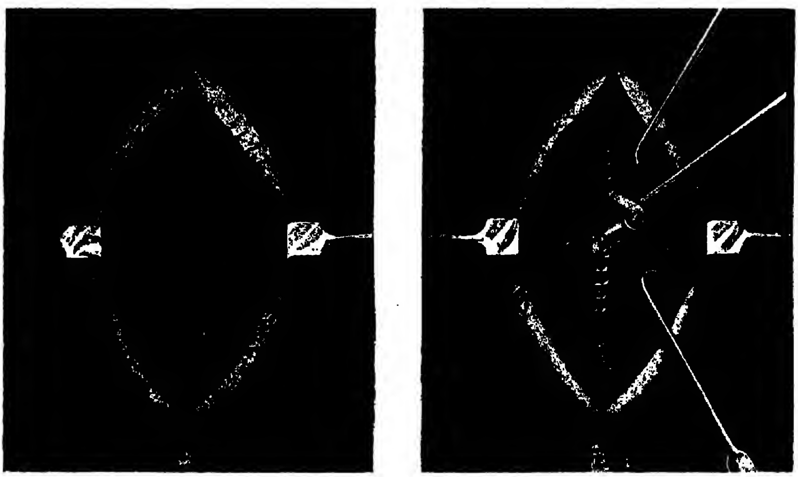


FIG. 85.—RECONSTRUCTIVE ENDO-ANEURISMORRHAPHY. (Matas.)

A, Showing the method of closing the orifices and of constructing a new arterial channel in a fusiform aneurism; B, removal of the guide. The same principle may be carried out more effectively with a continued suture.

choked limbs, or marked arteriosclerotic subjects, in whom the collateral circulation could with difficulty be restored. In these the preservation of the main channel would be necessary for the life of the limb. Subsequent experience has convinced me that the reconstructive operation (aneurismoplasty), while of proved value, is called for only in special cases, in which (*a*) the condition of the sac is especially favorable for the rebuilding of the lost artery; (*b*) cases in which there is good reason to fear the insufficiency of the collateral circulation, either by the rigidity and disease of the arteries from arteriosclerosis, or in consequence of obliteration and obstruction of the venous circulation. In this relatively small but dangerous class of cases the reconstruction of the artery may render great service as a *temporary* or permanent expedient by which the peripheral circulation may be *maintained* pending the development of the collateral circuit. While

in all traumatic cases in which there is no atheromatous disease of the affected artery it is possible to restore the continuity of the artery, I do not pretend that the walls of a diseased sac, in which the elasticity has been lost, will permit of the reconstruction of an artery possessed of the functional qualities of a normal healthy vessel. In these cases a new provisional channel is constructed which will save the limb, though it may be ultimately destined—(1) to undergo obliteration by progressive endarteritis or thrombosis; (2) to undergo secondary aneurismal dilatation. If the new channel is gradually obliterated, the circulation will have had an opportunity to readjust itself, and the result will be like that of an obliterative endo-aneurismorrhaphy or of an extirpation. If secondary dilatation and relapse take place, as have already happened in 2 cases, it will be safe to reopen the sac and then perform an obliterative endo-aneurismorrhaphy, as has been done successfully in the only case in which it has been attempted (Danna), on the assumption that the collateral circulation has had time to develop.

The Blood-pressure Test as an Aid in Determining the Choice of Operations (Korotkow's Method).—The conditions which must determine in any given instance whether a reconstructive operation is indicated or an obliterative operation can be performed with absolute safety or not, will never be answered satisfactorily until an unerring clinical test of the adequacy of the collateral circulation after the preliminary compression of the main trunk which feeds the aneurism shall be at our command. The method of determining the peripheral blood-pressure in the very tips of the extremities recently devised by the Russian surgeon, Korotkow, as the result of his experience with arteriovenous aneurisms in the Russo-Japanese War, and applied successfully by him, Petrov, and v. Oppel, may prove the final solution of the problem.

If the peripheral blood-pressure is shown by the manometer (a modified Gärtner's tonometer) to be more or less sustained after the compression of the main trunk above the aneurism, then the obliterative operation may be safely applied. If, on the other hand, the blood-pressure falls to zero, it is evident that the collateral circulation is inadequate and that no chance should be taken with the obliterative operation or with any procedure whatever (ligature, extirpation, etc.) which would permanently occlude the parent artery. There are, unfortunately, many fallacies which underlie the application of blood-pressure tests, especially where these are most needed, viz., in aneurisms of the popliteal, femoral, and iliac arteries. Furthermore, any test depending upon change of color in the extremities (*e. g.*, Gärtner's tonometer) is not only technically difficult to apply to the toes, but is practically worthless when used on negroes. Furthermore, in testing for the efficiency of the collateral circulation, the main trunk should be compressed immediately above the aneurism, and this is very difficult and practically impossible with the majority of popliteal, low femoral, iliofemoral, and iliac aneurisms. Therefore,

Korotkow's test is at present applicable only in the upper extremity, where it is less valuable.

In a general way it may be said that whenever the peripheral parts (digits, feet, or hands) remain cadaverically pale and cold and show no vascular flushing or active hyperemic blush upon removing an Esmarch elastic bandage while digital pressure is being maintained upon the main artery of the limb above the aneurism, and if the cadaveric appearance remains as long as the finger is kept on the main trunk, it will be well to delay operative interference with the hope that the collaterals may develop. However, whenever there is much edema and tension of the peri-aneurismal tissues, as in the popliteal region especially, it is evident that the more quickly the sac is evacuated the more promptly will the collateral circulation be relieved and improved.

When, however, there is no urgent need of interference and there is reason to suspect by the above tests that the collateral circuit is insufficient, it may be advantageous to resort to preliminary digital or instrumental compression of the main artery in order to develop the collaterals. Although this method has been utilized in practice for many years, and is largely lauded by the Japanese surgeons, whose large experience in the treatment of traumatic aneurisms entitles their opinions to special consideration, it is not to be trusted as reliable or as free from danger. It cannot be trusted in old atheromatous subjects with rigid arteries in whom, in addition, the prolonged compression of the main artery may lead to thrombosis and embolism in the distal parts with gangrene, thus bringing about just the result which the procedure is intended to avoid. In all traumatic cases, in young, vigorous, healthy subjects with elastic arteries, the preliminary compression of the artery should prove a valuable addition to the operative treatment. In all doubtful cases, in fact, in all cases, it is desirable not to operate too early after the development of the aneurism. Time should be given in acute traumatic aneurisms for the development of the sac to full maturity, not only to give time for the development of the collateral circulation, but also to favor the obliteration of the sac and of its orifices by intrasaccular suture. *Undue haste in operating on traumatic cases, especially when the sac-walls are not well lined with endothelium, will not permit of the easy closure of the orifice of the wounded artery, which still remains as a distinct trunk at the bottom of the cavity and will compel the application of an obliterative ligature on each side of the wound (intrasaccular ligature), when by a little delay the closure could often be accomplished without total obliteration.* The experience of the military surgeons, both Russian and Japanese, confirm all the advantages of delay in allowing the sac to form fully before operating, though their object in delaying operations was chiefly to give an opportunity to the collateral circulation to develop. In pathologic aneurisms, if the cautious compression of the main trunk and the gradual development of the aneurism are not followed by improvement in the arterial pressure after the temporary

digital obliteration of the main trunk, any obliterative procedure is contra-indicated, and gradual obliteration by Halsted's bands or by reconstructive endo-aneurismorrhaphy offers the only hope of cure without gangrene.

Commentaries on the General Technic.—The intrasaccular method is much simpler, easier, and safer than extirpation, because it is all conducted within the sac and the peri-aneurismal tissues are not exposed or disturbed. That it is not difficult of execution is attested by the fact that quite a number of the operations referred to have been performed successfully by young surgeons who began their apprenticeship in the treatment of aneurism by the performance of this operation. Judgment, however, is required in determining the class of cases in which the reconstructive operation is indicated, and also, after its selection is determined, in the mode of constructing the new tube. This should always be made by a continued stitch, which may be simply whipped over with an occasional recurrent (back-stitch) at intervals, in order to lock it and to secure perfect hemostatic sealing of the line of suture. The new channel should be of smaller caliber than that of the parent artery, as seen usually at the inlet and outlet of the aneurism, where the vessel often dilates into trumpet-shaped extremities; the suture should always take in the entire thickness of the sac-wall, up to its external layer, so as to obtain a firm grip of the tunics. It should always begin well above and beyond the margin of the proximal and distal orifices, in order to contract these gradually to the caliber of the new tube, which should be just large enough to allow the column of blood to go through easily; it should be about one-half the diameter of the parent vessel, with the view of favoring secondary obliteration rather than dilatation. The first line of sutures should always be reinforced when possible by an additional superimposed row of continued sutures taken through the folds of the relaxed and corrugated walls of the sac on each side of the first line of sutures. It is an error to believe that the smooth, glistening endothelial surfaces of the sac must be refreshed in order to secure better union, as some surgeons believe. The preliminary denudation of the margins to be sutured is injurious, and is no more necessary than the preliminary denudation of the endothelial layer of the peritoneum to secure a firm union of the serous surfaces. In fact, the more polished and glistening the endothelial surface, the better it is for plastic adhesion. In performing the reconstructive operation, a rubber tube of the estimated caliber should be used as a guide after it has been well lubricated with sterile vaselin (and the suturing material also) in order to diminish the tendency to thrombotic coagulation, as well shown by Carrel. In the obliterative operation, after closing the main orifices, careful search should be made everywhere for the openings of collaterals. This is aided by scrubbing the sac-wall with gauze soaked in sterile saline solution and wiping away the loosely adherent laminated clot. The organized and fully adherent pseudomembrane should remain undisturbed. The suture material is preferably No. 0 or 00 chromic catgut, or fine ophthalmic silk, dipped

in vaselin. The silk is especially indicated when fine needles are necessary to close small orifices. The best needles are the semi- and full-curved intestinal needles of the Hagedorn, Kirby, Mayo, and Fergusson type, or conjunctival needles. It should be mentioned that the suture of the aneurismal orifices is not so delicate an operation as lateral or circular arteriorrhaphy in a normal artery, for which only the finest needles (No. 16, 17, Kirby) and the finest silk or linen thread (No. 500) are suitable. The occlusion of the usually large orifices in an aneurismal sac is a comparatively gross affair, which any one can do well who is competent to close an intestinal perforation or perform a Witzel gastrostomy.

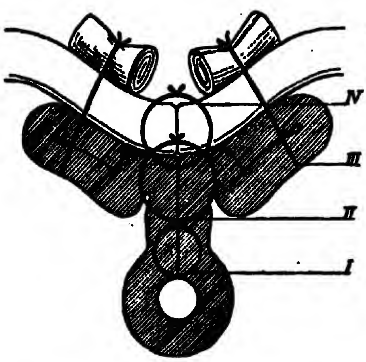


Fig. 86.

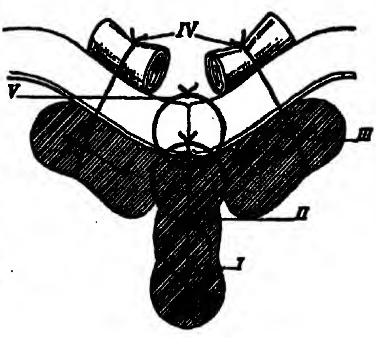


Fig. 87.

FIGS. 86, 87.—THE RADICAL CURE OF ANEURISM BY THE INTRASACCULAR METHOD. (Matas.) TREATMENT OF THE SAC BY METHOD I.

FIG. 86.—Diagram showing sectional view of the obliterated aneurismal sac when the lumen of the parent artery is preserved and the vessel originally communicates with the aneurism by a single orifice. (Restorative and reconstructive endo-aneurismorrhaphy.) *I*, First line of sutures which close the orifice of communication and restore the lumen of the parent vessel; *II*, second row of protecting sutures which also reduce the size of the sac; *III*, supporting through-and-through sutures, which bring the roof and floor of the aneurism in contact; *IV*, sutures which hold the skin-flap and sac in contact with the bottom of the cavity.

FIG. 87.—Section diagram showing method of obliterating the aneurismal sac in obliterative endo-aneurismorrhaphy. In this class of cases the tunics of the parent artery blend with the sac, and the arterial channel cannot usually be restored. The diagram shows the first row of sutures (*I*) which obliterates the orifice of the artery at the bottom of the sac. The second row of sutures is shown higher up (*II*), and also the effect of this row in reducing the capacity of the sac. The obliteration of the remaining part of the cavity by folding in or inverting the sac-walls with the attached overlying skin is shown in *III*. The function of the deep sutures (*IV*) tied over gauze pads, and of the more superficial skin sutures (*V*) in obtaining firm contact of the opposed surfaces, is also shown. This illustration is purely schematic, it gives an exaggerated idea of the size of the sac-walls, and is chiefly intended to give an idea of the position of the sutures and other parts.

Treatment of the Sac.—This is one of the distinctive features of the operation, and is susceptible of variations according to conditions. The fundamental point is that, in order to obliterate the cavity of the sac, the endothelial surfaces must be approximated so that no dead spaces are left behind.

Method I.—Total obliteration of the sac by suture and inversion of the skin-flaps.

In the large typical aneurisms, the collapse of the sac after incision and emptying of the clot is followed by the pleating or corrugation of the relaxed walls in longitudinal folds. In these cases my typical method of treating the sac is recommended. In a popliteal or a femoral aneurism, for example, the typical method, after the obliteration of the

orifices by separate suture, would consist in first taking up the lateral folds from the deepest part of the sac and bringing them together in the middle line by a continuous suture extending from one pole of the sac to the other, the folds being brought into apposition very much as folds of peritoneum would be brought together by a continued Lembert suture. If there is a surplus of material near the surface, it will be proper to contract the cavity still further by additional tiers of sutures, thus obliterating the deep part of the sac and bringing it much nearer the surface. Whatever remains of the sac is then turned upon itself with the superimposed and adherent skin-flaps which result from the primary incision (see Figs. 86, 87). In this way the wound is closed without leaving dead spaces and without need of drainage.

Method II.—Total obliteration of the sac by suture, *leaving the sac buried* in the wound, *without* inversion of the skin-flaps and without drainage.

This is indicated in comparatively small aneurisms in deep places and in muscular and fat subjects. In deep popliteal and femoral aneurisms especially, in which the skin-flaps will not stretch enough to reach to the bottom of the deep cavity, the obliteration of the sac is obtained by running through it a series of continued buried sutures in superimposed tiers, which bring together its entire inner surface. This method has been adopted more often than any other.

Method III.—The cavity of the sac is *not obliterated,* but is lined with sliding skin-flaps or grafts.

This method is similar to that adopted by Neuber in healing rigid bone cavities—"Capitonnage" of the French—and is reserved for those cases in which the sac is large and deep, with rigid bottom and walls, from old peri-aneurismal adhesions, or in some popliteal sacs which adhere to the posterior surface of the femur and to the ligaments of the knee-joints, the sac not collapsing or pleating in relaxed folds as in the majority of the cases. If possible, the skin-flaps should be *tacked* to the bottom with catgut sutures, or at least to the sides as far as they will stretch without risk of sloughing. If the cavity cannot be "Neuberized" in this way, in its entirety, as much of the walls as possible should be lined by skin and the remaining exposed surface should be skin-grafted or covered with silver-foil until granulations have formed, when it may be grafted. Usually the surface left uncovered is small enough to be covered by the relaxed skin-flaps. It is also possible that in some cases the entire raw surface may be covered by the help of relaxation, incision, and pedunculated flaps borrowed from the vicinity, but this should be avoided when the nutrition of the skin is impaired and there is risk of sloughing from ischemia.

Method IV.—In ruptured and infected sacs with irregular intermuscular diverticula, it is often impossible and undesirable to attempt the obliteration of the dead spaces. In these cases, after the suture of the orifices, and after complete hemostasis has been secured, the adherent healthy remnants of the sac may be obliterated and the detached and superfluous parts excised. The deep wound can be

contracted in places with buried sutures, and the remaining space lightly packed with sterile or antiseptic iodoform gauze soaked in balsam of Peru, which can be allowed to remain for a week or longer until a firm granulation layer is obtained.

Method V.—For intraperitoneal cases—*e. g.*, iliac aneurisms. In these the sac is not disturbed from its peritoneal cover and the serosa is utilized with even greater advantage than the skin-flaps in the same manner as that prescribed for external aneurisms. After the hemostatic suture, the sac is totally obliterated by internal suture and the peritoneum is closed over the level of the sac, or the sac is partially obliterated by intrasaccular suture and the remaining space is infolded upon itself, including the peritoneal surfaces of the sac flaps, which are brought into apposition and held in place by transfixion or by a continued row of Lembert sutures.

Prophylactic hemostasis is absolutely essential, not only for the protection of the patient, but also for the proper methodic and deliberate application of the suture technic. In the peripheral aneurisms, beyond the root of the limb (popliteal, femoral, brachial), absolute hemostasis is obtained by Esmarch's constrictor after the limb has been drained by elevation or gravity. In the aneurisms of the root of limbs (inguinal, axillary, subclavian, and carotid) the preliminary hemostasis can only be obtained by securing the parent trunk above and below the aneurism, and as near the sac as possible, without dissecting it. For this purpose I have devised a special clamp which compresses the artery at each pole of the sac and below it so as to control the vessels given off immediately at the entrance and the exit of the artery into and from the sac; but ordinary curved, long, soft elastic clamps of the Doyen model will also accomplish the purpose. In the groin severe hemorrhage may occur from the profunda upon opening the sac, even after the common femoral has been controlled by proximal traction loop or clamp. In these cases, to avoid the recurrent flow from the obturator, gluteal and sciatic, it is the safer plan to begin the operation by a preliminary laparotomy, which will allow the *common* iliac to be compressed with a traction loop or a clamp held by an assistant. While this is being done, it will also be advantageous to compress the abdominal aorta, especially during the moment when the sac is opened. This secures an absolutely bloodless field and permits the operator to work in the aneurism with perfect ease and deliberation.[1] In subclavian aneurisms the innominate should be compressed with a traction loop in aneurisms of the first or middle third, on account of profuse bleeding from the vertebral and internal mammary and of other branches.

Endo-aneurismorrhaphy is indicated in every form of peripheral or internal aneurisms in which the method of extirpation or of Antyllus is practicable. It is just as radical an operation as the methods hitherto

[1] Sometimes, in spite of aortic compression, the epigastric may bleed into the sac, as in a recent iliofemoral aneurism I operated upon. This vessel is easily controlled by digital pressure and clamping in the sac.

applied for the cure of aneurism, and has all the advantages of extirpation with none of their dangers or disadvantages. In the restorative and reconstructive types of the operation, it not only spares the collateral circulation in its entirety, but it restores the parent trunk permanently in the sacciform cases and provisionally (in all probability) in the fusiform arteriosclerotic cases. In this way it deliberately challenges for the first time in surgical history the law laid down by Scarpa, which has remained an immutable and unshaken principle in surgery from the time it was first enunciated by that remarkable surgeon over one hundred years ago to the present time. According to Scarpa, "it is a certain and incontrovertible fact in practical surgery that a complete and *radical* cure of aneurism cannot be obtained in whatever part of the body this tumor (aneurism) is situated unless the ulcerated, lacerated, or wounded artery from which the aneurism is derived is, by the assistance of nature, or of nature combined with art, obliterated and converted into a perfectly solid ligamentous substance, from a certain space above and below the place of the ulceration, laceration, or wound." This ultimatum, so thoroughly confirmed by the experience of surgery (see the evidence in the monumental work of Ballance and Edmunds, loc. cit.), is no longer tenable as an absolute truth, since the substitution of the suture for the ligature has permitted the aneurismal sac, in a very considerable percentage of the cases, to be obliterated without interrupting the continuity of the parent artery.

Statistical Conclusions.[1]—On June 1, 1908, when I submitted my last summary of the reported cases of endo-aneurismorrhaphy at the meeting of the Surgical Section of the Amernica Medical Association, held in Chicago (Jour. Amer. Med. Assoc., Nov. 14, 1908), I reported 85 cases, operated by 52 surgeons (49 American and 3 foreign). Seventy-seven of these operations should be classed as typical and 8 as atypical. The arteries involved were distributed as follows: External iliac, 1; gluteal, 1; iliofemoral, 5; femoral, 18; popliteal, 50; posterior tibial, 1; external carotid, 1; subclavian, 1; subclavio-axillary, 2; axillary, 1; brachial, 2; aortic, 2. Total, 85. Over 58 per cent. were popliteal; over 21 per cent. femoral. Of these 85 operations, 59 were of the obliterative type (69 per cent.); 13 of the restorative type (15.4 per cent.); and 13 of the reconstructive type (15.4 per cent.).

Of the 50 popliteal aneurisms, 28 were treated by the obliterative method, 8 by the restorative, and 10 by the reconstructive. Of the 18 femoral, 11 were obliterative, 6 restorative, 1 reconstructive. Of the 85 patients, 78 recovered; 7 died; 4 suffered from gangrene (of some part of the lower extremities); 4 relapsed (only in the reconstructive cases). In the obliterative group (59 cases) there were 6 deaths; in the restorative (13 cases), no deaths; in the reconstructive (13 cases), 1 death. Secondary hemorrhage occurred once

[1] Since this publication in June, 1908, and while this article is going through press, I have received further reports which have increased the statistics of endo-aneurismorrhaphy from 85 to 110 cases, a large proportion of which (17) are popliteal, femoral, and iliac—all recoveries without gangrene.

in the obliterative group (iliofemoral), none in the restorative, and once in the reconstructive (popliteal); total secondary hemorrhage, 2. Of the 7 postoperative deaths, 5 should be eliminated from the list as not attributable to the method, but to accidental circumstances common to wounds in general; thus: tetanus, 1 case (Stafford); pulmonary embolism, 1 (Levi Old); rupture of a secondary aneurism (iliac) at a distance from original (femoral) aneurism, 1 (Stafford); 2 abdominal aortic aneurisms (Lozano and Munro), in which the condition of the vessel precluded the satisfactory application of provisional hemostasis. If these 5 cases are eliminated, the mortality would be reduced from 7 to 2 deaths in 85 cases, or 2.3 per cent.; gangrene, 4 in 85 cases, occurred only in obliterative operations (4.6 per cent.), but if we eliminate two popliteal aneurisms, in which the vein was simultaneously ligated for accidental injury (Lozano, Stafford), and 1 iliofemoral, in which gangrene followed the ligature of the external iliac for hemorrhage in the sac at a lower point, the percentage of gangrene legitimately attributable to the intrasaccular operation would be 1 in 85, or 1.1 per cent.

Relapses.—These occurred only in the reconstructive operations (4 in 13 operations); 28.9 per cent. of the group, or of the total, 4 per cent. It is to be noted that in one of these cases the aneurism was cured permanently after the relapse by a secondary obliterative operation (popliteal, Danna), and from a previous knowledge of the conditions existing in the sac in two other cases, one popliteal (Morris) and one iliofemoral (Danna), there is every reason to believe that a permanent cure could have been safely effected if the sac had been reopened and obliterated after the relapse following the reconstructive operation had been recognized.

In only one case (popliteal, Binnie) the local conditions would have been apparently unfavorable to any form of local intervention.

In view of the fact that the cases reported have been largely compiled after diligent search in the United States and without any attempt at selection, these statistics are remarkably satisfactory when compared with those of extirpation and other methods in which a very considerable percentage of the fatal or unfortunate cases fail to appear.

It is interesting to note that many of the operations reported in my collection of endo-aneurismorrhaphies have been successfully performed by young surgeons who have begun their apprenticeship in the surgical treatment of aneurism by the intrasaccular operation.

It is evident that the intrasaccular method cannot cope with thoracic or abdominal aneurisms unless those be of the sacciform type, in which the sac can be obliterated without occluding the lumen of the parent artery. The unfavorable conditions in both cases thus far reported are well illustrated by Lozano's case, in which the aorta crushed like an egg-shell under the clamps applied to obtain provisional control of the circulation. In these cases better results may be expected from gradual obliteration by Halsted's metallic rings, though even then the

diseased arteries may become thrombosed or ulcerate, with fatal secondary hemorrhage.

In fine, while the intrasaccular method aims at and accomplishes a cure of the aneurism with greater safety to the limb and life of the patient, there will always remain certain cases in which gangrene will occur from embolism or thrombosis or other unavoidable and accidental causes, which are started into activity whenever the circulation is even provisionally arrested for hemostatic purposes, as in Frazier's case.

(IV) **The Method of Intrasaccular Ligature (the Method of Syme and Annandale).**—This method is applicable to *traumatic aneurisms* with or without fully formed adventitious sacs of recent formation, in which the wounded artery is recognized at the bottom of the sac and is damaged too extensively to permit of lateral or circular arteriorrhaphy. In the majority of these cases, in which the walls of the sac are well defined and the edges of the wounded artery are continuous with those of the new sac-wall, the *obliterative, restorative*, or *reconstructive* types of the intrasaccular method of suture (endo-aneurismorrhaphy), according to conditions, are not only more easily applied, but are safer.

FIG. 88.—ANNANDALE'S METHOD OF INTRASACCULAR LIGATURE. (Annandale.)

a, Orifice leading to nutrient artery of aneurismal sac; *b*, metal catheter used as a guide; *c-d*, two small incisions made on each side of the guide to allow the aneurism needle (*e*) to carry the ligature around and under the artery.

The intrasaccular ligature of the main artery inside of the aneurismal sac was practised by Syme (1861) and Annandale, of Edinburg (1885), who advised that the orifice be searched for in the sac of traumatic aneurisms and, after finding it, in order to facilitate the ligature of the trunk, that a probe or catheter be introduced as a guide into the lumen of the artery upward on the proximal side and downward toward the periphery. A small incision was then to be made through the floor of the sac, on each side of the orifice, corresponding to the wound in the artery. Through this small incision a ligature was to be carried around the vessel and tied, the catheter being withdrawn as the ligature was tied. The same maneuver was to be repeated on the proximal side, and in this way the bleeding orifice was completely controlled without dissecting the sac in its entirety, avoiding the disturbances in the peri-aneurismal tissues that would be necessitated by an extrasaccular ligature or by a total extirpation. This excellent suggestion, which is quite effective in pure traumatic aneurisms, is not as satisfactory in the spontaneous or pathologic aneurisms, in which the aneurismal

sac is formed at the expense of the tunics of the parent artery. In the spontaneous fusiform and sacciform aneurisms the segment of the artery involved in the aneurismal process gives off important and often large collaterals, especially in the upper femoral, popliteal, axillary, and subclavian aneurisms. Therefore, the mere ligature of the main vessel in the sac is not sufficient to arrest the hemorrhage which follows in the sac upon the removal of the constrictor. It is thus necessary, if the ligation is relied upon as the sole hemostatic agent, that the sac be dissected out or extirpated in order to ligate the individual vessels as they penetrate into the sac from the outside. Possibly, for this and other reasons, the ligation of the main artery, as suggested by Annandale, was not generalized in practice, and the ligature *in situ*—*i. e.*, at the bleeding point, according to the long-established golden rule—was not carried out by surgeons except in ligating the recently wounded arteries in which diffuse and progressive pulsating hematomas demanded prompt interference.

The rules for the ligature of wounded arteries and the pulsating hematomas have been sufficiently discussed in the section on the Surgery of the Arteries, and need no further commentary. In connection with the treatment of traumatic aneurisms, it is interesting to notice that the forgotten suggestion of Syme and Annandale has been revived and systematized into a method (without a previous knowledge of this suggestion) by Kikuzi and other Japanese surgeons, who in the late Manchurian struggle have been compelled to face the treatment of traumatic aneurisms on a large and extended scale, such as have never been witnessed before in the annals of military surgery. Thus, Kikuzi reports 86 operations for traumatic aneurisms, Tanaka reports 110 operations, and Saigo, 36. The German and Russian surgeons on the Russian side likewise report the frequency of these aneurisms, both arterial and arteriovenous. These observations, which simply confirm on a large scale the earlier experiences of the English and Boer surgeons in the South African war, all agree in the conclusion that since the advent of the modern small hard-jacketed projectile in modern warfare, wounds of the large vessels have immensely increased, and that primary hemorrhage, even when the large vessels of the neck and extremities were involved, has become an insignificant factor in the mortality of the field hospitals. This remarkable absence of serious primary hemorrhage is counterbalanced by the certainty with which secondary arterial and arteriovenous aneurisms follow after such wounds. In view of the ease with which the primary hemorrhage is usually controlled by the ordinary first-aid dressing, moderate compression, etc., it became a rule, observed by all the Japanese surgeons and the majority of the Russians (except, notably, Zoege von Manteuffel), never to operate upon these patients in the field hospitals. It was only when progressive and diffuse hematomas occurred in the course of transportation that operative interference by ligation of the bleeding artery at the bleeding point was regarded as necessary or justifiable. All operative treatment was reserved for the stationary hospitals,

where the aneurisms which invariably developed were allowed to mature into fully formed aneurismal sacs.

Experience has shown that in traumatic aneurisms, well-defined circumscribed adventitious sacs, lined by new endothelium, will form within a comparatively short time, sometimes in three days, and after arteriovenous injury within a few hours. Usually the wound tract is well healed and cicatrized when the pulsating tumor is large enough to be felt. Leo Bornhaupt states that these aneurisms should not be touched before a period of four to six weeks has elapsed, and in this Kikuzi, Saigo, and the other surgeons concur with him. The object of this delay is not only to eliminate all possibility of primary infection, but also to give the collateral circulation a good opportunity to develop. Kikuzi furthermore observes that when the operation is delayed, the proximal and distal ends of the divided artery as seen in the sac are quite often contracted and narrowed, apparently as the result of the compressive action of the expanding tumor itself. The spontaneous cures noticed in thoracic aneurisms by Makins and other surgeons in the South African war no doubt are accounted for, in part at least, by this well-known obliterative action of the tumor upon the feeding vessel. Loison, writing of traumatic aneurisms in civil practice, also urges delay in operating, with the view of favoring the development of the collateral circulation. I myself have likewise long contended that it is preferable to wait for the aneurism to develop into a well-formed tumor, not only in traumatic, but in spontaneous, aneurisms, with the double object of favoring the development of the collaterals and of allowing the newly formed sac in traumatic cases to become lined with newly formed endothelium. The false sacs thus formed are intimately adherent to the surrounding perivascular tissues, and their removal by extirpation entails much and severe traumatism. To obviate the injury to the collaterals which usually follows the extirpation of large sacs, especially at the root of the limbs, Kikuzi was led to adopt his "intrasaccular operation," in which the peri-aneurismal tissues are resected and the ligation of the wounded vessels is conducted exclusively within the sac. In his earlier experience Kikuzi performed typical extirpations, then he was led to adopt a modified Antyllus, which he did as follows, taking a femoral aneurism of the middle third as an illustration: He exposed the femoral vessels by incision, as near the sac as possible; no Esmarch or constrictor was used. After exposing the vessels, the artery was divided between two ligatures; in arteriovenous aneurisms, the vein was likewise isolated and cut between two ligatures. After this was done, the constrictor was applied to the root of the limb, after ischemia had been obtained by elevation and drainage. The incision was then prolonged over the whole length of the tumor and the sac opened and evacuated. After clearly exposing the bottom of the sac, the ligated trunk of the artery connected with the sac was untied, and a catheter or long probe was inserted into the lumen, which acted as an unerring guide to the opening

of the artery in the interior of the sac; in arteriovenous aneurisms the guide was similarly introduced into the vein.

By adopting this procedure, the orifice of the wounded artery is at once identified in the sac, and the outline of the parent artery on the proximal and distal side of the wound readily made out as it lies under the sac-walls. Having identified the path of the artery in this way, it is easy to isolate it and dissect it out through the sac-walls. The wounded segment is then excised for a short distance on each side of the perforation, and the proximal and distal ends are ligated separately. The vessel is thereby secured without disturbing the peri-aneurismal tissues, and with much less traumatism and delay than would follow a formal attempt at the extirpation of the sac. With increasing experience, Kikuzi was soon convinced that the preliminary extrasaccular dissection and division of the parent trunk was unnecessary, as it was quite easy, in the majority of the cases, to locate the bleeding orifice at the bottom of the sac, especially when a clear and dry surface was obtained by carefully wiping off the adherent clots. Therefore, method No. II was adopted as follows: Ischemia of the limb is obtained by elevation, gravity, and the elastic constrictor. The aneurismal tumor is opened freely and emptied. The bottom of the sac is exposed and the wound orifice is located. If there is difficulty in identifying the opening, the constrictor is relaxed sufficiently to reveal the bleeding point. When this is seen, a probe is introduced into the opening, upward toward the trunk and downward toward the periphery. The outline of the main vessel is thus plainly made out, and a ligature is applied over the guide through the sac and around the vessel, in the manner suggested by Annandale, and the vessels secured on each side and a short distance from the opening. Kikuzi, who is very well pleased with the results of the intrasaccular ligature, justly claims that, in comparison with the old Antyllian method and that of extirpation, it has great advantages, in so far (1) that it greatly simplifies the operation; (2) that it shortens the time required to perform it; (3) that in favorable cases it may be performed with local anesthesia; (4) that the obliterated section of the artery is much shorter than by extirpation; (5) that only a few collateral branches are lost; (6) that the circulatory disturbances and the dangers of peripheral gangrene are consequently diminished. After the intrasaccular orifices are closed and hemostasis has been obtained, an iodoform gauze drain is left in the sac and the external wound is partially closed with sutures, over which an occlusive and immobolizing dressing is applied. It will be observed by this description that the reasons which led Kikuzi and the Japanese surgeons to adopt this intrasaccular procedure are precisely the same as those which led me long before them to apply the method of endo-aneurismorrhaphy or intrasaccular *suture*, which had been successfully practised in America many years before they had conceived it as a result of the experiences of the Manchurian War. It is also just as applicable to pathologic as well as

to traumatic aneurisms, and in many cases it will also permit of the restoration of the continuity of the parent trunk.

Kikuzi says that he has had but one case of gangrene following all his operations (85 cases). Saigo, who operated on 36 cases, had 2 deaths, 1 after an Antyllus and 1 after extirpation; 2 secondary hemorrhages, 1 after an Antyllus and 1 after extirpation; 2 gangrenes of the upper extremities after ligation of the axillary and subclavian respectively; 1 gangrene of the leg after double ligature of the femoral vessels for varix; 1 gangrene of the toes after extirpation.

A group of methods will now be described and only briefly referred to, because they have been carried out only in isolated instances by individual operators, but which deserve attention as showing the efforts of clinicians in applying the facts recently acquired by laboratory workers in the domain of experimental surgery. They are largely the outcome of the original work of J. B. Murphy, of Chicago (1897), who first suggested the possibility of extirpating aneurisms in a few suitable cases and restoring the continuity of the parent artery by lateral and circular arteriorrhaphy. Since the impetus given to arterial suture, both experimentally and clinically, the value of this procedure has been so thoroughly appreciated and its technic has been so much perfected, especially by the work of Carrel and those who have adopted his technic, that it is not surprising that surgeons should have attempted to carry out not only the technic of arteriorrhaphy, but also that of the transplantation and grafting of segments of arteries or veins in the treatment of both arterial and arteriovenous aneurisms. In attempting to classify the few clinical cases thus far recorded we shall class them in accordance with a definite principle or plan adopted by each operator, thus:

(V) (*a*) **Aneurismectomy** associated with **Lateral Arteriorrhaphy.**—This procedure is only applicable to sacciform aneurisms with narrow necks. Many cases of traumatic diffuse hematomas without distinct sacs have been reported since Murphy operated on the first case, in which the wound in the artery or vein, or both (arteriovenous aneurisms), have been closed by suture; but in this discussion only the aneurisms with fully formed sacs are considered. The only case of extirpation with lateral arteriorrhaphy is that recorded by Garrè of Leipsic. The operation was performed in 1904 on a patient aged twenty-six years. An arteriovenous aneurism had been accidentally caused by a puncture, with a pocket-knife, of both femoral vessels about the level of Hunter's canal. The tumor had existed ten years. It was formed by a large oblong sac, which was attached by a narrow neck to the wounded vessels. The extirpation of the sac was completed after a very difficult and laborious dissection. The vein was divided between ligatures at its point of attachment to the sac. The collar of the sac was left attached to the arterial walls and closed with continuous silk sutures. Pulsation was detected in the popliteal artery, but not in the dorsalis pedis, where it was distinctly felt before the operation. The patient recovered.

In connection with arteriovenous aneurisms, we shall show that lateral arteriorrhaphy and phleborrhaphy are not only legitimate procedures, but should be the method of election whenever it is possible to retain the continuity of the injured vessels.

(*b*) **Aneurismectomy Associated with Circular Arteriorrhaphy.**—In a case reported by Erich Lexer, of Königsberg, he extirpated a sac about the size of the fist, which was connected with both the popliteal artery and vein. The injury had been inflicted thirty-one days previously with a pen-knife. A large number of veins, attached to the sac, had to be dissected out and divided. After resecting the closely adherent sac which had already formed, the popliteal vein and artery had to be resected. When the isolation of the vessels was completed it was found that the injury involved so much of the circumference that lateral suture of either vessel was impossible. On account of the serious danger to the limb from the extensive traumatism during the

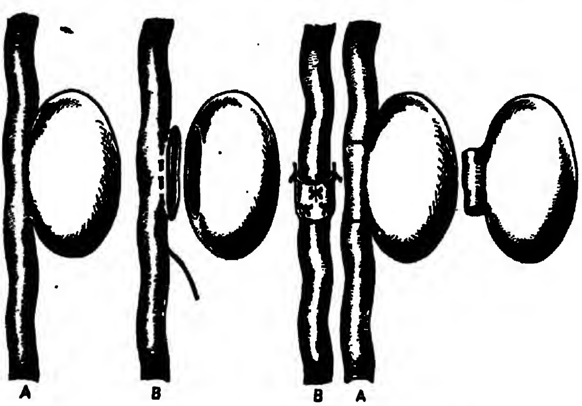


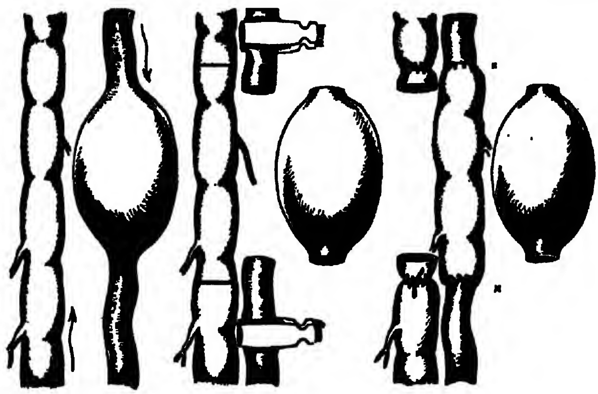
FIG. 89.—ANEURISMECTOMY FOR SACCIFORM ANEURISM, WITH LATERAL OR CIRCULAR ARTERIORRHAPHY. (Murphy's suggestion.)

1, The sac is resected in B, and the collar of sac is sutured so as to preserve the lumen of the artery (performed once in 1906 by Garre; 2, A, extirpation of the aneurism with a segment of the artery; B, the artery reunited by Murphy's invagination method. This operation has never been performed.

extirpation, Lexer brought the divided vessels together by circular arteriorrhaphy and phleborrhaphy. This approximation of the divided vessels, which amounted to 5 cm., could not have been accomplished without flexing the knee at right angles. In this instance the anastomosis was effected by using Payr's magnesium rings. After the removal of the constrictor the artery pulsated and blood flowed into the vein. The limb was immobilized in plaster-of-Paris dressing, which was removed after six weeks. After the sixth week the knee could be extended, and the patient was discharged in eight weeks, with partial ankylosis of the knee-joint. Eight months after the operation the pulse in the dorsalis pedis could hardly be felt, suggesting a progressive obliteration of the artery at the anastomosis. A similar operation is reported by Stich (Bonn) for aneurism of the popliteal artery, in which the Carrel technic was successfully applied in July,

1908; and another popliteal, by Enderlen (Würzburg), in December, 1907, a simplified Carrel circular technic being successfully adopted. The advantage of flexion in permitting the approximation of the divided arteries after resection is well illustrated in these cases, but when the excision is large, flexion is not sufficient, and if the continuity of the artery is to be restored, other methods must be adopted. This leads to:

(VI) **Aneurismectomy with Arteriovenous Anastomosis, with (a) Venous Transplantation, (b) Arterial Transplantation.**—Of the first group there are only two instances on record, one, a case of *uniterminal* venous transplantation reported by Goyanes, of Madrid. He reported a case of fusiform popliteo-femoral aneurism which began in Hunter's canal in a man aged forty-one years. Adopting the technic of Carrel, he divided both vessels on a level with the



1 2 3

FIG. 90.—ANEURISMECTOMY WITH BITERMINAL VENOUS TRANSPLANTATION. (Lexer.)

In this operation the sac is extirpated or displaced to one side and a segment of the satellite vein is substituted for the missing section of the artery by the Carrel method of biterminal venous transplantation. 1 shows aneurism and vein side by side; 2, aneurismal sac detached from the artery and displaced; 3, the segment of the vein is united to both ends of the artery in order to restore the arterial circulation. By this procedure the main vein is sacrificed, and if the transplanted venous segment becomes blocked by thrombus, the distal circulation may be seriously endangered. This operation has been performed once successfully by Lexer, of Königsberg.

abductor. Then the *peripheral* end of the artery and the *central* end of the vein were closed, and the *central* arterial end was united to the *peripheral* venous end. The blood-current readily passed over the anastomotic joint immediately after the removal of the hemostatic clamps. The aneurismal sac was merely displaced to one side, still attached to the peripheral end of the artery. In spite of suppuration the patient recovered and was well five and a half months after the operation.

Aneurismectomy with Grafting of Transplanted Vein (*Biterminal Venous Transplantation*).—This case is reported by Lexer and deals with a traumatic aneurism of the axillary artery following a dislocation of the shoulder-joint. The patient was sixty-nine years old and the injury had been inflicted nine weeks previously. There was extreme arteriosclerosis. Impressed by the good results obtained by

Stich, Makkas, and Dowmann, who had followed in the wake of Carrel in transplantation of vascular segments. Lexer, having previously controlled the axillary with Hoepfner's clamps, incised the tumor and removed a large mass of blood-clot. There was no formed aneurismal sac. The axillary was found too badly lacerated to permit of either lateral or circular arteriorrhaphy. Three cm. of the artery were resected, the stumps at once retracting 8 cm. apart. The gap between the divided vessels could not be bridged over. Fearing gangrene of the extremity, a segment of the long saphenous vein large enough to meet both ends of the artery was transplanted from the thigh and united by circular arteriorrhaphy (Carrel's technic) to each end of the artery. The anastomosis was not difficult, because the lumen of the vein and artery were nearly equal. On removing the hemostatic clamp the blood rushed into the venous segment and was felt at the ulnar artery, but not at the radial. The operation took forty-five minutes. The dislocation also was reduced. To give the anastomosis a firm support the grafted segment was buried in the anterior surface of the deltoid. The patient and the arm did well until the third day. Delirium set in on the fourth and all circulation ceased in the arm on the fifth day, followed by gangrene and death from cardiac exhaustion. A thrombus had formed in the axillary at the point of compression by the forceps. The lumen was perfectly pervious at the anastomotic joints.

Aneurismectomy with Arterial Transplantation or Grafting *(Biterminal Arterial Transplantation)*.—Delbet reports a case of femoropopliteal aneurism. The application of this procedure was based upon the success of Hoepfner (1903) in restoring the continuity of arteries by grafting sections or segments of arteries transplanted from one part of the arterial system to another, as from the carotid to the femoral of the same animal, and then from one animal to another, Hoepfner using Payr's technic. Carrel and Guthrie went farther, and not only succeeded in establishing heteroplastic arterial transplantations, but also arteriovenous transplantations, applying Carrel's simple suture method. Since then Carrel has been able to graft successfully arterial segments of variable dimensions which have been kept in Locke's solution in cold storage for forty days. Impressed with these experimental facts, Delbet tried the transplantation of a popliteal artery (obtained from a freshly amputated leg) in place of the artery excised, in extirpating a femoropopliteal aneurism. Delbet's patient was an atheromatous man, aged seventy-four years, who had a very large femoropopliteal aneurism. Fearing that the peripheral circulation would not be reëstablished, Delbet had made arrangements with a colleague in another hospital to operate on the aneurism simultaneously with the amputation of a leg. The attempt to graft the popliteal of the amputated leg failed because of the extreme chalky degeneration of the arteries in the aneurismal patient. The attempt had to be abandoned and the stump of the resected artery had to be ligated. The ligature on the proximal side cut through the artery and when the constrictor was removed the patient had a formidable hemorrhage; after another failure

the femoral had to be ligated in Hunter's canal. Gangrene set in and amputation of the leg became necessary.

It is evident from what has been said that the indications for the combined extirpation of aneurisms and the suture of the vessels to restore the circulation must be very limited in pure arterial aneurisms, and the substitution of grafted vessels for missing arteries still less frequent, and applicable only as an extreme measure. The great disadvantage of these procedures is that in the efforts to extirpate the sac irremediable damage is inflicted on the collateral vessels and peri-aneurismal tissues; the situation is still further complicated when the satellite vein is sacrificed and used to restore the continuity of the artery. If the anastomosis is unsuccessful and the operation fails, then the death of the limb is inevitable, as all the collateral avenues of the circulation have been destroyed.

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ARTERIOVENOUS ANEURISMS.

Definition.—All abnormal communications established between an arterial and a venous channel, whether it be an artery and a vein or an artery and a sinus of the dura mater (pulsating exophthalmos), or with a venous plexus, constitute arteriovenous aneurisms.

Classification.—The communication between an artery and a vein may be *direct* or *indirect.* On this basis there are two types of arteriovenous aneurism: (1) The aneurismal varix; (2) the varicose

FIG. 91—ARTERIOVENOUS FISTULA WITH IMMEDIATE COMMUNICATION (BROCA); ANEURISMAL VARIX.

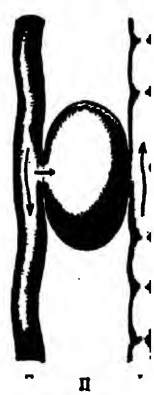

FIG. 92.—ARTERIOVENOUS ANEURISM WITH FALSE INTERMEDIARY SAC (*aneurysma varicosum*).

FIG. 93. — ARTERIOVENOUS ANEURISM WITH ARTERIAL SAC. SECONDARY VARICOSE ANEURISM.

aneurism (aneurysma varicosum). In *aneurismal varix* the arterial and venous wounds become agglutinated and adherent as a direct sequel to the injury, and an arteriovenous fistula is established after the small perivascular extravasations have been absorbed. In traumatic *varicose aneurism* the normal anatomic position of the vessels is disturbed, the injury is followed by a more or less extensive hemorrhage, which becoming circumscribed by the resistance of the perivascular tissues, forms a well-defined pulsating hematoma, and finally an encysted and well-differentiated sac.

Usually when an arteriovenous anastomosis is established, the vein, on account of its weaker walls, yields progressively under the steady pressure of the arterial current, unless, as often happens, a resisting sheath and aponeurosis are strong enough to counteract the arterial pressure. If this extravascular support is missing the vein dilates and assumes a sacciform or fusiform shape opposite the seat of the fistula, and in this way the *varicose aneurisms by dilatation* (Broca) are formed. Sometimes the dilatation in the veins may attain such enormous size as to be mistaken for an independent tumor. The sub-varieties of these two fundamental types are numerous, and have received various confusing designations according to the preponderance of the dilatation on the arterial or on the venous side, or both. These types will be more clearly understood by referring to the accompanying diagrams suggested by Fischer and Lexer (Figs. 91–98).

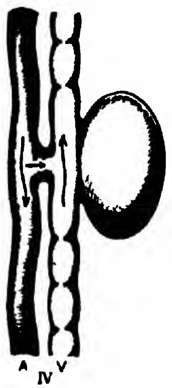

FIG. 94.—ARTERIOVENOUS FISTULA WITH VENOUS SAC.

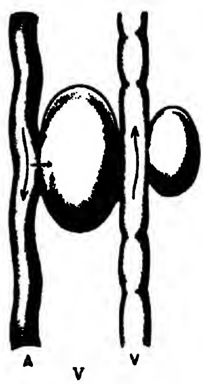

FIG. 95.—ARTERIOVENOUS ANEURISM WITH FALSE INTERMEDIARY SAC AND VARIX ON OUTER SIDE OF VEIN DUE TO DOUBLE INJURY OF THE LATTER.

In addition to these varieties the complete division of both the artery and vein by stab or shot will lead to the formation of a false sac, showing in its interior two *proximal* and two *distal* openings, corresponding to the cardiac and the peripheral orifices of the vessels divided (Fig. 97). Amussat, in his early experimental work, noted that after complete division of the main artery and vein only the two central vascular stumps entered into communication with the newly formed sac, "direct aneurism with a blind sac," the two peripheral ends being occluded by thrombotic material. A similar formation may occur in amputation stumps (Fischer).

Secondary arteriovenous aneurisms are those found usually in the neighborhood of the heart when a primary aortic aneurism gradually ulcerates or opens by pressure atrophy into a venous channel, such as the vena cava, pulmonary artery, right auricle or ventricle.

Other rarer varieties exist in which both vessels are completely divided. The peripheral end of the vein is obliterated by thrombus, the two arterial orifices and the central venous orifice communicate

with the same sac. Other cases are recorded in which the *afferent* and not the *efferent* arterial branches were found, and still other rarer varieties which are described in the literature.

Etiology and Pathogenesis.—Etiologically, arteriovenous aneurisms may be classified into: (1) Traumatic; (2) spontaneous or idiopathic; (3) secondary; (4) so-called congenital.

Traumatism is the most frequent cause by far of arteriovenous aneurisms; by bullet wounds, as exemplified most notably in modern military practice, or by a clean narrow puncture or stab wound. At a time when venesection was practised, often twice yearly, arteriovenous aneurisms at the bend of the elbow were of common occurrence as a result of puncture of the brachial or ulnar arteries while opening the median basilic vein. Even as late as 1888 Delbet's statistics of 250 cases of arteriovenous aneurisms show that in 96 the ulnar artery was in-

FIG. 96. — ARTERIOVENOUS ANEURISM WITH IMMEDIATE COMMUNICATION (FISTULA) AND SAC ON THE ARTERIAL SIDE. (SINGLE VENOUS AND DOUBLE ARTERIAL INJURY.)

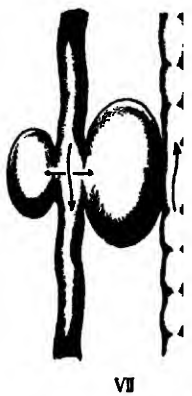

FIG. 97. —ARTERIOVENOUS ANEURISM WITH FALSE INTERMEDIARY SAC AND AN ARTERIAL ANEURISM DUE TO A SINGLE VENOUS AND DOUBLE ARTERIAL INJURY.

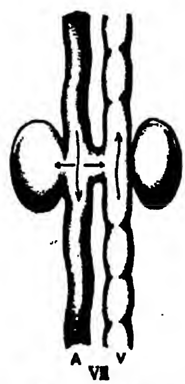

FIG. 98. — ARTERIOVENOUS FISTULA WITH OPPOSING SACS, DUE TO A DOUBLE INJURY OF BOTH VESSELS.

volved, no doubt in consequence of venesection. Von Bramann, in his classical study of the subject in 1886, mentions 56 cases caused by venesection. Of 158 cases of peripheral aneurism collected by von Bramann in 1885, 108 followed after punctured or incised wounds, 29 after gunshot wounds, 5 after contusions, 9 occurred spontaneously, 1 from an abscess, and 1 from an amputation stump. It is probable that at the present time the relative preponderance of punctured and gunshot wounds as a cause of these aneurisms has been reversed, and that gunshot wounds have the first rank, both in peace and war, especially in the United States and English-speaking countries, where the revolver is the weapon of offense and defense.

In his official report on the "Surgical Cases Noted in the South African War, 1899–1902," Surgeon-General W. F. Stevenson (London, 1905) reports 63 cases of traumatic aneurism. Of these 63 aneurisms,

33 were of the arteriovenous type, practically 50 per cent. In the Russo-Japanese War the proportion was nearly the same.

Pathogenesis.—The reasons for the greater frequency of aneurisms in modern warfare have already been referred to; suffice it to say that the conditions necessary for the formation of ordinary arterial traumatic (false) aneurisms are those required for the production of arteriovenous aneurisms—"small orifice of entrance and exit of the bullet; a narrow but long curved channel, usually crossing the course of the vessel in an oblique direction; a small perforation in the artery, followed by rapid closure of the wound and primary union of the bullet track" (von Bergmann). These are the conditions which now obtain in modern warfare, and to a large extent in civil practice, when small-caliber projectiles are used.

Uncomplicated cases of aneurismal varix are less common than those in which the arteriovenous communication is accompanied by the formation of a traumatic sac. The most important conditions which determine the formation of the aneurismal varix are the *proximity* and degree of cohesion of the two vessels, the comparative spaciousness, or the opposite, of the vascular cleft, and the degree of support afforded by the surrounding structures (Makins). Thus the close proximity of the popliteal vessels, of the femoral vessels in Hunter's canal, to a less extent at the groin, and of the carotid sheath, account for the greater frequency of this type of arteriovenous anastomosis in these regions than elsewhere.

Apart from bullet and punctured wounds arteriovenous aneurisms may be caused by subcutaneous fractures (more often at the base of the skull) and the erosion of the vessels by acute and chronic suppurations.

The spontaneous origin of arteriovenous aneurisms of the peripheral arteries of the body is extremely rare. When it occurs it is usually as a sequel or complication of arterial aneurisms, the aneurismal sac forming adhesions with the neighboring vein, the two vessels communicating by an erosion or atrophy of the intermediary partition; 42 cases of this kind were compiled by Barwell; Boinet increased the list to 114, of which 39 involved the ascending aorta and superior vena cava, 5 the aorta and innominate, 20 the aorta and right cavities of the heart, 30 between the aorta and the pulmonary artery, and 20 of the aorta and inferior vena cava. In very exceptional cases the arteriovenous communications are established by septal abscesses, which ulcerate through the walls of the contiguous vessels. The aneurismal varices which occur in amputation stumps have been repeatedly observed. They are usually associated with massive ligature of both vessels, followed by infection.

The so-called *congenital* arteriovenous aneurisms described by some authors are to be regarded as varieties of cirsoid aneurisms, in which communication is established between an artery and a vein in the plexus at an advanced stage of the disease.

Pathologic Anatomy and Physiopathology.—The pathologic anatomy of arteriovenous aneurisms is most interesting as an illustration of adaptation of structure to function. The artery, at the seat of the

anastomosis, becomes dilated, tortuous, especially in long-standing cases, its walls become thinner, less elastic and less resistant; the muscular elements become atrophied. The afferent end of the artery shows usually the least changes; the distal arterial segment becomes contracted and is narrower, since it receives less blood and is subjected to much less blood-pressure than normal. On the other hand, the entrance of the arterial stream into the vein immediately causes a rise of the blood tension of the vein, followed by a dilatation and yielding of its walls in proportion to the size of the orifice of communication, the volume of arterial blood poured in, and the relative support the vein receives from the perivascular structures. Dilatation takes place up to the first valve in the peripheral segment; this valve, as well as those lower down toward the periphery, gradually yield in proportion to the increase in the intravenous tension; the resistance of the valves favors the dilatation of the vein in segments, as in the varicose state, the dilated segments forming tumors which vary from the size of a pea to that of a large egg or even of the fetal head, as in the very exceptional case related by Osler. The dilatation on the peripheral segment of the vein is very much influenced by the resistance of the peri-aneurismal tissues. With the dilatation consequent upon increased intravenous pressure, there is a coincident thickening and hypertrophy of the venous walls and even valves. As shown by Quénu, the muscular coat of the vein becomes very much hypertrophied, the fibers increase in number, a veritable hyperplasia occurs, showing that compensation for the unusual pressure has occurred in the venous wall and that the vein becomes in a manner *arterialized*, to cope better with the abnormal conditions. The marked "arterialization" of the veins has been confirmed by all experimenters, but by none more conclusively than by Alexis Carrel, who has demonstrated the possibility of interposing a segment of excised vein into an arterial defect several centimeters long by a double end-to-end suture (biterminal transplantation). "Aided by the support of the surrounding tissues and by its own hypertrophy, the interposed segment of vein, after a temporary slight ballooning, soon effectively plays the part of the thick-walled artery for which it has been substituted."

When an aneurismal sac becomes interposed between the artery and the vein its walls rarely present the same regular homogeneous appearance which characterizes the arterial aneurisms. In many places the sac is simply recognizable as such, but in all fully developed aneurisms the interior is lined throughout by a smooth layer of endothelium, which has formed by proliferation from the interior of both vessels.

A notable peculiarity of the sac in varicose aneurisms is that it scarcely ever contains a clot, especially of the laminated, active type, which characterizes the arterial aneurisms. The circulation in these aneurisms is too active to allow of the formation of any coagula. This lack of clot is important in differentiating between the pure arterial and the arteriovenous aneurisms, and also in accounting for the slight, if any, tendency to spontaneous obliteration displayed by the sacs of varicose aneurisms.

Progress and Evolution.—Arteriovenous aneurisms rarely attain large dimensions. There is no progressive dilatation of the arterial tunics, or large deposits of clot, or secondary ruptures, which continue to increase the size of the sac in pure arterial aneurism. But while the sac of varicose aneurisms usually remains stationary, it shows no tendency to spontaneous cure by coagulation.

Secondary Lesions and Effects.—In consequence of the abnormal circulatory conditions changes occur in the artery on the distal side of the anastomosis, resulting from contraction of the lumen from disuse. Ischemia of the territory supplied by the injured artery is felt according to the amount of blood deviated into the anastomosing vein. Complete stenosis and thrombosis with varix formation on the peripheral venous side must occur in certain areas in consequence of the forced entrance of arterial blood and the damming back of the venous current. In other limited areas the nutrition of the affected parts is favored by the more abundant supply of arterial blood, but this occurs to a very limited extent only. This results at first in hypertrophy, followed later by retrogressive processes in the involved organs. The deficient blood-supply and the imperfect exchange of gases interfere with the nutritional conditions of the body segment supplied by the injured artery, resulting in a number of pathologic degenerative and involutionary states of the various tissues and organs. Edematous infiltration and hypertrophy of the subcutaneous connective tissue are followed by subsequent atrophy of the skin and histologic changes akin to those which accompany ordinary varicose veins. The skeletal muscles become atrophied and undergo degeneration. The nerves likewise suffer from the circulatory disturbances, and the trophoneurotic phennomena observed in the old cases, especially of the lower extremities, are due to this cause.

The distant and remote effects of arteriovenous anastomosis will be marked in proportion with the importance of the vessels involved. It is important to bear in mind, however, that the aneurismal varices of the neck and upper extremities are especially well tolerated; they give rise to comparatively little subjective disturbance, except the noises, which sometimes are heard by the patients themselves. In the lower extremities the effects of the overplus of blood and damming back of the venous circulation are more pronounced.

Gangrene of the digits and peripheral parts occurs occasionally, but very rarely, indeed, in comparison with the frequency of this occurrence in arterial aneurism. As a whole, an indolent career—no tendency to progressive enlargement, no tendency to rupture, no tendency to spontaneous peripheral gangrene—is the general characteristic of this type of aneurism.

Experimental Arteriovenous Aneurisms.—Three types of arteriovenous aneurisms have been reproduced experimentally: (1) Lateral (direct) arteriovenous anastomosis or aneurismal varix; (2) lateral (mediate) arteriovenous anastomosis with intermediary sac (varicose aneurism); (3) end-to-end arteriovenous anastomosis or uniterminal

arteriovenous anastomosis. Biterminal arteriovenous anastomoses are to be classed in a group apart with the vascular transplantations or grafts (see section on Arteries). The object aimed at by experimenters in establishing these anastomoses has been quite different according to the point of view: (1) To study the physiologic phenomena resulting from the abnormal conditions of the circulation. In this category must be included the early experiments of François Franck (1881–1887), Vignolo (1902), and of Franz (1905), in all of which most valuable data were obtained of practical application to the symptomatology and clinical history of the disease. (2) Artificial production of arteriovenous anastomoses with the view of utilizing the venous channels as carriers of arterial blood when for any reason the arteries become functionless. The object here was to determine to what extent the conditions of the circulation could be reversed so that the veins could be made to act as arteries. All these observers were impressed with the comparative benignity of simple direct aneurismal varices and their tolerance by the organism without serious evil effects for indefinite periods of time. In this category San Martin y Satrustegui, of Madrid, stands first. Bérard and Carrel, Jaboulay and Briau, Gallois and Pinatelle, Goyanes, all largely inspired by the previous efforts of San Martin and Jaboulay, contributed experiments to this entirely new therapeutic phase of the problem of "*arterializing*" the veins. It was reserved to Alexis Carrel (1902), however, to elaborate a simple method by which arteriovenous anastomoses could be accomplished with unfailing precision and without secondary thrombotic obliteration (see Carrel's Method, Surgery of the Arteries). It is this method which has been adopted by all the laboratory workers who have since succeeded in repeating Carrel's experiments in vascular anastomosis and grafting. Jaboulay and his followers were also inspired by the idea that in cases of cerebral softening from obliterative endarteritis or thrombus of the circle of Willis or after ligature of the carotids, the functional disorders consequent upon cerebral ischemia might be averted by irrigating the brain with arterial blood injected through the jugular vein, the circulation being reversed in the neck by anastomosing the central end of the carotid to the peripheral end of the jugular. While it does not appear that this procedure has been attempted clinically in man, though experimentally successful in animals, the reversal of circulation has been attempted at least twelve times since San Martin first tried it in the femoral vessels in 1902 for the purpose of arresting progressive gangrene of arterial origin in the lower extremities. While these clinical experiments do not appear to have been crowned with much success, as far as the effect in arresting the gangrene is concerned, they have shown that the technic of arteriovenous anastomosis is perfectly feasible in the human subject, and that in the clinic, as in the laboratory, the veins can be depended upon as reliable substitutes for damaged or obstructed arteries. While it is doubtful that the arterialization of the veins in a complete histologic sense,

including the capillary circuit, will ever be realized, even under the most favorable circumstances, on account of the innumerable anastomoses between the superficial and deep venous plexuses, as Delbet has pointed out, these experiments are of capital importance for the future progress of surgery in proving the reliability of the technic of arteriovenous anastomosis and transplantation.

Symptomatology.—An extremely variable period may elapse between the infliction of the injury and the appearance of the signs, which indicates that an arteriovenous anastomosis has been established. In a study of the arteriovenous aneurisms of the subclavian compiled by myself (18 cases up to 1902), the characteristic thrill was fully developed four hours after the injury (revolver bullet) in my own patient. In 3 cases the sign appeared on the second day, in 3 on the third day, in 1 on the eighth, and in 1 on the ninth day. While the symptoms of arteriovenous anastomosis may appear almost coincidently with the injury, it is far more frequent that an interval of weeks should elapse, and months and years have elapsed in a few very rare cases. As the wounds that lead to arteriovenous aneurism are usually punctured or gunshot with long narrow tracts, the primary bleeding is rarely excessive or very alarming, even when the great vessels, like the subclavian, carotid, or femoral, are injured. In modern warfare primary hemorrhage from the wounds caused by projectiles fired by small-bore rifles rarely require the primary ligation of the vessels. As a rule, the hemorrhage subsides after the application of moderate pressure and of the dressings. The wound heals without reaction, while the edges of the perforation in the artery and vein become agglutinated to each other, any possible temporary obstacle to the anastomosis by clots being quickly overcome by the onrush of the arterial current. Ordinarily a local swelling is found at the seat of injury, at first diffuse, and continuing to enlarge in the first few days. Ecchymoses and visible discolorations of the skin will be recognized when the injured vessels lie near the surface. The swelling in a few days will gradually become better defined, harder, and distinctly circumscribed. The process of limitation and contraction may continue, the sac becoming stationary, or ultimately disappear, and a pure varix be the result. Occasionally the opposite course will be followed and fresh extension takes place, as evidenced by enlargement of the tumor, with disappearance of sharp definition, by softening, and pain. The natural termination in such a case would no doubt be rupture and possible death in some regions and loss of limb in others. The tendency to contract and to the limitation of the process is by far the most frequent event.

Thrill.—If the swelling or wounded area is palpated, the establishment of the anastomosis will be made known immediately by the *thrill* transmitted to the fingers on palpation. This peculiar purring thrill, as it is well called, is pathognomonic of arteriovenous aneurisms whenever it is felt, and, indeed, it is rarely absent. This thrill is appreciated, both by the tactile and auditory sense, when the vein on

the peripheral or proximal side of the anastomosis is exposed, as in operations; it becomes appreciable to the eye as well by a *visible* vibration in consonance with the thrill felt on palpation. The thrill is always felt with maximum intensity at the seat of the anastomosis and is intensified with each cardiac systole. On auscultation, in addition to the thrill, a continuous bruit is heard, which is reinforced with each systole of the heart. This murmur, which has been compared to the sound produced by a bee in a paper bag, or the "whirr" and "buzz" of machinery, is just as characteristic of arteriovenous aneurisms as the thrill, and when the murmur and the thrill are present together the diagnosis is unmistakable. The constant whirring bruit presents, however, marked variations in pitch and strength, which accounts for the variety of impressions it has conveyed to different observers—"the purring of a cat," "the droning of bees," "the humming of a top," etc. These noises in aneurisms of the carotid and subclavian regions are frequently heard by the patients, who complain of them as the only inconvenience from the disease. When an arteriovenous anastomosis exists in the subclavian, the murmur and thrill will be heard in all the superficial veins of the neck and arm down to the hand. In the femoral region it will diffuse itself to the ankle and up to the umbilicus. Sometimes, though very rarely, the murmur may be so intense that it will be heard over the seat of the anastomosis by listening close to the skin with a stethoscope, but without touching it directly. The thrill, bruit, and all the signs of arteriovenous aneurism may be made to cease completely by compressing the orifice of communication with the finger-tip. The elevation of the limb, according to Nélaton, is sufficient to transform the usually constant murmur into an interrupted one.

Different theories have been proposed to account for the peculiar noises and thrill which characterize this class of aneurisms. Webber, Maray, Cheauvau and Mil, v. Wahl have shown that the sounds are produced by vibration of the blood, and not the vibration of the edges of the membrane bordering the fistula. Franz states that the thrill and murmurs depend upon the free flow of arterial blood in the *central* segment of the vein. The peripheral segment of the vein is not related to these phenomena. The murmur is transmitted in a *centrifugal* direction, even when the peripheral portion of the vein is transposed purposely, as in experimental work. When the *central* segment of the vein is closed to the arterial flow by ligature or by thrombosis, then the continuous murmur becomes intermittent and loses its venous blowing character (Franz).

Changes in the Pulse.—The arteries and veins above and below the seat of the anastomosis usually present marked changes. On the proximal side of the aneurism the arterial pulse is full and strong, more marked than on the normal side. The compression of the artery on the proximal side will also suppress the tumor, if it exists, as well as all the aneurismal phenomena. If the artery is felt below (on the distal side of the tumor), the pulse will be found to be weaker and smaller.

The compression of the artery on the distal side near the sac will intensify the pulsation, thrill, and all the aneurismal signs. The superficial veins above and below the sac are dilated, sometimes tortuous, and pulsate synchronously with the arterial pulse.

The sphygmographic tracings, as taken by Franz in his experimental researches, show: (*a*) Anacrotism (Ebenan), which is interpreted as the effect of the *arterial* blood on the peripheral portion of the vein, and in varicose aneurisms with an intermediate sac an expression of the effect on the wall of the latter. (*b*) The graphic curves of the central venous and peripheral arterial ends agree in so far as they present a low wave-like line.

The circulatory disturbances produced immediately after the establishment of the arterial venous fistula cause an immediate lowering of the peripheral temperature; however, a certain compensation soon follows. This compensation may, as far as the collaterals extend, produce *over the site of the anastomosis* an increase in the temperature on the affected limb; the parts of the extremity farthest removed from the anastomosis always show a decreased temperature.

Remote Effects on the General Circulation.—Disturbances of a grave character must follow in the general arterial blood-pressure whenever the arterial blood-stream is directed from its proper course in the arteries to the venous system. Thus Carrel saw death follow promptly in dogs when a direct end-to-end anastomosis was established between the abdominal aorta and vena cava. The capacity of the venous system being so much greater than the arterial, and the pressure of the venous blood so much lower than the arterial, it is easy to conceive that the arterial stream may all be drained into the venous side, leaving the arteries practically empty. Grave disturbances have been noted in arteriovenous aneurisms in which the larger vessels were involved, the circulatory disturbances being proportionate with the size of the orifice and the volume of arterial blood side-tracked into the veins. These general disturbances are manifested chiefly by a tendency to faintness and rapid pulse, the pulse oscillating between 120 and 130 in many cases, until an adjustment of conditions or tolerance has been established (Makins, Freyer). In the smaller vessels, or when the orifice of communication is small, the general disturbances are insignificant. The local effects also vary with the degree of obstruction placed upon the return venous current by the incoming arterial blood-stream, and also by the amount of blood deviated from the main arterial channel at the seat of the anastomosis. It is evident that the greater the deviation of the blood-stream the more marked will be the effects of venous obstruction and arterial ischemia. These local effects are manifested as varices, edema, followed by thickening and connective-tissue hyperplasia. Sometimes an elephantiasic condition develops as the result of persistent venous and lymphatic stasis. Dusky discoloration or cyanotic hue in the legs has occasionally been noticed. Hypothermia is subjectively expressed as a general sensation of cold in the limbs beyond the anastomosis. The contradictory evidences of Bramann, Knaak,

and Bardeleben, who found the temperature lower (4 to 8 degrees less on the affected side), and of Broca and Delbet, who found it increased in popliteal aneurisms (2 to 4 degrees), are reconciled by the experimental evidence of Franz, who shows that, while the temperature at the seat of the fistula may be actually increased by collateral compensation, it is always lower and below normal in the distal part beyond the aneurism. We have already referred to the secondary changes which occur in the lower limbs especially as a result of arterial ischemia and venous congestion—all the dermal changes (desquamation, eczema, and trophic ulcers) which accompany chronic varicose veins are associated with progressive muscular atrophy, emaciation, paresthesias, neuralgias, formication, and physical disability—all testifying to the defective nutrition of the limb in the more typical and advanced cases.

Diagnosis.—The diagnosis of arteriovenous aneurism in typical cases is very easy and offers no special difficulties. Given the history of injury over the path of large vessels, the attention of the observer and possibly of the patient himself will at once be attracted by the thrill felt over a large area in the vicinity of the arteriovenous communication. The combination of (*a*) purring thrill, (*b*) *continuous* buzzing or machinery murmur reinforced by each systolic contraction, (*c*) the wide centrifugal transmission of the murmur, and (*d*) pulsation of the superficial veins will clinch the diagnosis.

The differential diagnosis between aneurismal varix and varicose aneurism can only be made out clinically when the vessels are situated superficially. Aneurismal varix is characterized by the presence of a vaguely outlined semispherical swelling, which may be felt through the skin or the cicatrix and rarely exceeds a walnut in size. It can be made to disappear by gentle steady pressure. It may also be made to disappear by compression of the main artery on the proximal side, the swelling reappearing after the removal of the compression. Compression below, on the artery or vein, will increase its size and intensify all the aneurismal signs. If the point where the thrill and murmur are heard with the greatest intensity is compressed directly, all the physical phenomena will cease at once (Vanzetti's sign).

In varicose aneurisms the tumor formed by the intermediary sac is larger; it cannot be altogether reduced, either by direct compression or by compression on the proximal side of the artery. Vanzetti's sign cannot be obtained as readily as in varicose aneurism. In some comparatively rare cases, in spite of the long existence of an arteriovenous anastomosis, varicose veins may exist, and yet no murmur or thrill be present when the venous segment on the central side of the anastomosis happens to be obliterated. The case may then be readily mistaken for varicose veins (Delbet, Terrier).

From arterial aneurisms the differential diagnosis is made by the purring thrill and the *continuous* "machinery," bruit, which is reinforced by each systolic contraction and is propagated centrifugally and centripetally along the veins. In addition to the absence of all these

accessory signs, the murmurs heard in arterial aneurisms are *intermittent* and heard only during the cardiac systole.

From cirsoid aneurisms the diagnosis is made by the fact that a bunch or congeries of vessels enter into the formation of this tumor, which originates *sine trauma*, and in special locations, scalp and face, and is not limited to isolated surgical trunks.

Prognosis.—The relatively benign course and tendencies of simple aneurismal varix have been recognized by all observers. The fact that individuals may tolerate this lesion indefinitely, especially when situated in the neck and upper extremities, with little or no inconvenience, has not only been well substantiated by the accumulated experience of the past, but is judged so favorably from the prognostic point of view that a considerable number of experimenters and practical surgeons have not hesitated to create artificial aneurismal varices, deliberately planned and executed, with the hope of utilizing the veins as substitutes for obliterated or damaged arteries.

Varicose aneurisms, on the other hand, should be regarded with more prognostic reserve and caution. While, unlike the pure arterial aneurisms, they rarely tend to enlarge or rupture (unless the artery undergoes aneurismal change), the blood entering the false sac readily finds its way into the venous lumen, so that the full force of the blood-pressure is never brought to bear upon the walls of the sac. Bramann and Delbet have shown that the benign tendencies of this class of aneurisms have been exaggerated and are rather relative than real. They have reached the conclusion that even aneurismal varix is always associated with local disturbances of function in the affected limbs or regions, though it must be recognized that in many of these the inconvenience and disability is remarkably insignificant. In contrast with the relative benignity and tolerance of these arteriovenous communications is the fact that they rarely tend to spontaneous cure (Broca, Bramann, Delbet), though the experience of the last few years in military practice has shown that in aneurismal varix spontaneous cure may be expected in a certain percentage of the cases. Spontaneous cure in varicose aneurism cannot be expected, as the spontaneous coagulation of the sac contents is made practically impossible by the great activity of the intra-aneurismal circulation. In the lower extremity, where the evils of venous stasis combined with arterial ischemia are much more severely felt than in the upper extremity, it is evident that interference is fully justified before the evil effects of the varicose state have been fully established.

Treatment.—All the methods of treatment which have been proposed for the cure of arterial aneurism have likewise been applied to the arteriovenous variety. Early in the surgical history of this condition it became apparent that the methods of compression and ligature, which were fairly successful in the treatment of arterial aneurisms, failed signally to cure arteriovenous aneurisms, and that when they did succeed, by obliterating the main vascular tracts, the disastrous effects upon the peripheral circulation—gangrene—were far

greater than those which followed the same procedures in pure arterial aneurism. It is not surprising that in the face of bitter and disappointing experience conservatism and abstention from operative interference should have become the rule of practice. This "notable disinclination to interfere in aneurismal varix and varicose aneurism, which characterized the attitude of the older surgeons, even long after the ligature of the blood-vessels had become a possible and successful operation," was encouraged and supported by the fact, long established by clinical observation, that in a large percentage of these cases the abnormal arteriovenous communication was remarkably well tolerated by the organism, and that the existence of such a lesion, even in the more important vascular tracts (carotid, subclavian, iliac, femoral), was not incompatible with a long and useful life. The tolerance and relative indifference which may be exhibited by a large number of individuals to the simple type (arteriovenous fistula) of this vascular lesion, when contrasted with the uncertainty and the risks which attach to the operative treatment of this condition, especially when the lesion involves the great vessels of the neck and root of limbs, still justifies a conservative and discriminating attitude.

While there is a considerable divergence of opinion on the question of interference or non-interference in arteriovenous aneurisms, one phase of the question has been definitely decided by the collective and overwhelming testimony of the military surgeons in recent wars—viz., that arteriovenous injuries, like simple arterial wounds, should not be interfered with as long as they are not associated with diffuse or progressive hemorrhage (Makins, Bornhaupt, Brentano, Saigo, Kikuzi). The wisdom of this policy has been so well attested by the results that its application to civil as well as military practice is desirable. As long as there is no urgent primary or secondary hemorrhage delay is advantageous, not only to allow the injured tissues to recover from local shock, trauma, and infection, but to favor the development of the collateral circulation. By "armed expectation" the tendencies of the lesion toward evolution or involution are observed, the possibility of spontaneous cure under appropriate treatment is encouraged, and the development of a defective collateral circulation is artificially promoted by the surgeon (digital compression on the proximal side, so much insisted upon by Bramann and the surgeons who have followed him (1885), especially by Kikuzi, Saigo, and other Japanese surgeons, as a preliminary to operative interference). In all recent cases of arteriovenous injury, especially those involving the great vascular trunks of the neck and lower extremities, in addition to the careful antiseptic and occlusive treatment of the wound with the view of obtaining primary union, the patient should be given the benefit of the most complete *circulatory* and functional (local) rest, as far as possible. Immobilization should be obtained, with gentle but firm pressure over the anastomotic connections, using plaster-of-Paris dressings, if necessary, for this purpose. Should no further extension or, what is more likely, should contraction and diminution occur, it will be well to continue this

treatment for some weeks at least (Makins). I am thoroughly in accord with Makins, who says: "My own opinion is strong and to the effect that none of these operations [proximal and local ligature and direct incision] should be undertaken before a period of two or three months after the injury unless there is evidence of progressive enlargement. In every case which came under my own observation progressive contraction and consolidation took place up to a certain point under the influence of rest. When the process has become stationary and the surrounding tissues have regained to a great extent their normal conditions, the operation is far easier and more likely to be followed by success." Not only are more favorable conditions obtained by delay, but even complete symptomatic cure, as shown by ancient as well as recent experience, can be obtained, which is tantamount to an actual cure. On the other hand, while delay and non-interference is advised for suitable non-active aneurismal varices, we must not lose sight of the fact that all arteriovenous aneurisms involve the artery in the injury, and that pure arterial aneurism, with its progressive tendency to rupture and hemorrhage, may develop after a period of apparent quiescence. Operative interference is indicated and becomes mandatory whenever a varicose aneurism shows a tendency to progressive enlargement, when there are signs of venous stasis, varicose veins, and trophoneurotic disturbances in the limbs, and, in fact, whenever functional disability of any sort is caused by the arteriovenous lesions.

Whenever this occurs, and operative treatment is decided upon, the next question which suggests itself is, What is the best treatment? Formerly the risk of hemorrhage, shock, infection, and gangrene faced the venturesome operator, and a frightful mortality followed in the wake of what were seemingly the simplest procedures. Hemorrhage, infection, and, to a large extent, shock have been eliminated by modern technic, but unfortunately gangrene still remains a menace and penalty whenever methods are adopted which obliterate the main channels of the circulation, either the artery or the vein, or both. Hence the preference that must be given to any method which will obliterate the anastomosis without interrupting the continuity of the parent vessels. This ideal result can be obtained wherever prophylactic hemostasis is possible, either by (1) direct incision over the aneurismal varix, with careful isolation and dissection of both parent trunks and ligation of the intermediary connecting channel (Liddell's suggestion), only applicable to very rare cases of simple aneurismal varix; (2) direct incision over the aneurismal varix, with extirpation of an intermediary sac when this is present, isolation and dissection of the vessels, followed by separate suture of the arterial and venous orifices by lateral arteriorrhaphy and phleborrhaphy. This ideal method has been carried out successfully by a number of operators—viz., Zoege von Manteuffel (1895), femoral vessels; Cammagio (1898), femoral vessels; Gérard Marchant (1898), brachial suture; Penguiez, of Amiens (1900), who operated at the bend of the elbow, suturing the artery and ligating the vein; Matas, of New Orleans (1902), who sutured the sub-

clavian vein and was compelled to ligate the artery on each side of the anastomosis; Koerte (1904), who detached a popliteal varix and sutured each vessel separately; Olivèr, of Uruguay (1904), who sutured the femoral vessels separately; J. A. Danna, of New Orleans (1905), who sutured the femoral vessels separately; Garrè, of Leipsic (1906), who extirpated a large sac, ligated the vein, and restored the continuity of the artery by lateral suture (Fig. 99); again by Matas (1907, unpublished), who restored both vessels in Hunter's canal by lateral arterior-

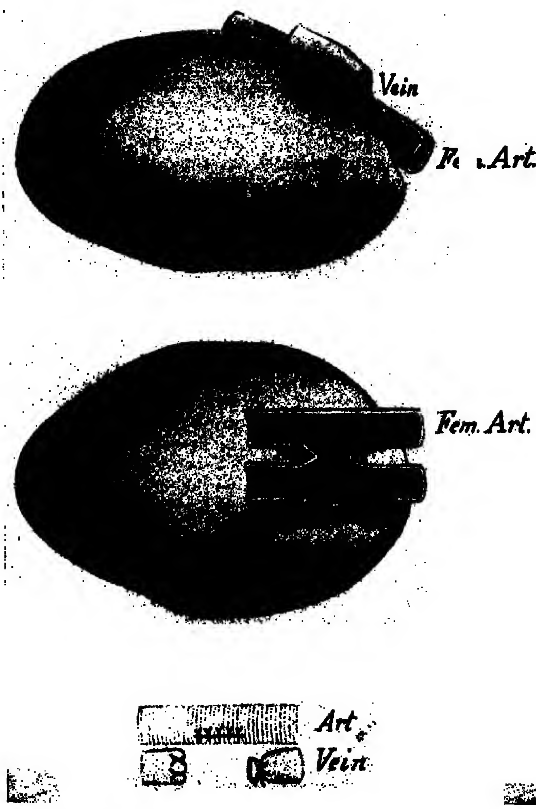

FIG. 99.—EXCISION OF SAC IN VARICOSE ANEURISM, WITH RESECTION OF THE VEIN, WHICH WAS LIGATED.
Lateral suture of opening in the artery (Garrè). Deutsch. Zeit. Chir., Bd. lxxxii., Hft. 46.

rhaphy and phleborrhaphy. In all these cases the arteriovenous aneurisms were of traumatic and recent origin. In a different category must be placed the first and most notable case operated upon by J. B. Murphy, of Chicago (1897), in which the femoral vein at Scarpa's triangle was sutured laterally and the artery, too much damaged for lateral suture, was resected and united by invagination; Lexer, of Königsberg (1897), also reports a case of popliteal aneurism involving both vessels (Fig. 90), in which both vessels were united after resection by direct

end-to-end arteriorrhaphy and phleborrhaphy (Payr's method). (See Treatment of Aneurism.) By the preceding methods excellent results (all successful without gangrene) have been obtained, but in many cases not without inflicting very severe and extensive traumatism (see Garrè's and Lexer's cases). To obviate the damage done to the perivascular tissues, especially when in old cases false sacs had formed, the method of endo-aneurismorrhaphy or intrasaccular suture should prove highly advantageous (Gessner's case, New Orleans, 1906). Instead of attempting an extirpation of the sac, the aim of the operator should be simply to open it and to obliterate by suture all the openings which may be found in its interior (see Endo-aneurismorrhaphy). The accompanying illustrations and legends, copied from W. S. Bickham's admirable contribution on the subject, show plainly how this very simple principle of suturing (instead of ligating) vascular orifices can be advantageously applied to both aneurismal varices and varicose aneurism. When both vessels (artery and vein) have been divided, and the continuity of the parent trunks has been completely interrupted, a

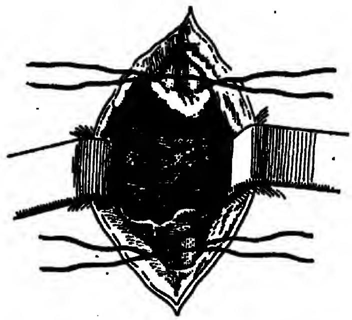

FIG. 100.—EXTIRPATION OF AN ARTERIOVENOUS ANEURISM "EN BLOC," THE ARTERY AND VEIN LIGATED ABOVE AND BELOW THE SAC BEFORE EXTIRPATION (Lejars).

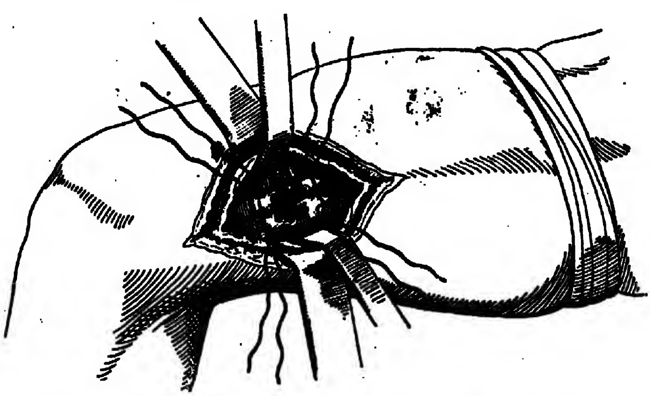

FIG. 101.—THE LIGATION OF THE ARTERY AND VEIN ABOVE AND BELOW THE WOUND IN EACH VESSEL IN ARTERIOVENOUS ANEURISM.

The intrasaccular ligature, or method of Syme-Annandale; also known as the "Japanese method of Kikuzi."

sac will form between the divided ends of the vessels, in which, on opening the sac, the four orifices of the divided vessels should be sought for and sutured. The usual practice has been to extirpate the sac and ligate the four vascular stumps separately. This procedure may damage the collateral circulation unnecessarily and imperils the limb, whereas

intrasaccular suture (obliterative aneurismorrhaphy) obliterates the orifices and the aneurism without interfering with the peri-aneurismal circulation. The success obtained by Annandale years ago, and by Kikuzi, on a much larger scale, by the method of intrasaccular ligature (see Fig. 101), and by Saigo and Tanaka, with extirpation, all argue well for the success of the intrasaccular suture in arteriovenous aneurisms, because it accomplishes not only all that is done by the ligature, but also with far greater simplicity than the ligature. Furthermore, the suture will permit the restoration of the continuity of the artery when-

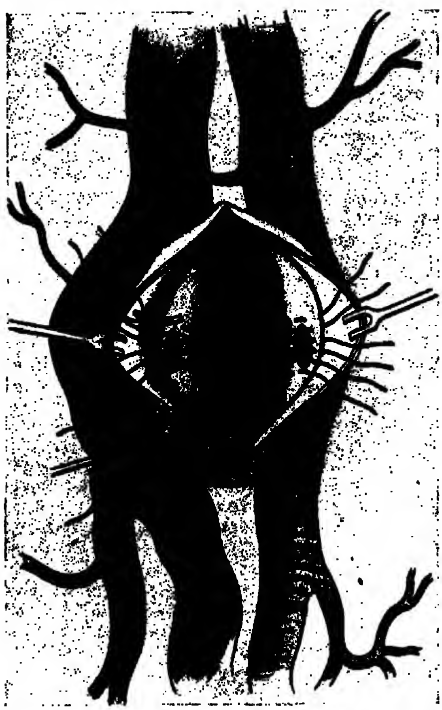

FIG. 102.—VARICOSE ANEURISM TYPE OF ARTERIOVENOUS ANEURISM OF LEFT COMMON FEMORAL ARTERY AND VEIN, SHOWING THE APPLICATION TO THIS CLASS OF ANEURISMS OF THE MATAS METHOD OF OPERATING UPON ORDINARY ANEURISMS.

The opening of the femoral artery into the common aneurismal sac is shown on the right, with interrupted Lembert gut sutures in position, ready to be tied. The opening of the femoral vein is seen on the left, with similar Lembert sutures in position. On the left of the sac two gut sutures are in the act of being placed, which, when tied, will approximate the roof of the sac (including skin and intervening tissues, which are not here shown) to the floor of the sac. Similar sutures will approximate the roof and floor of the sac upon the right (Bickham, in Ann. of Surg., May, 1904).

ever the condition of the vessel will justify it. When obliteration alone is possible, the suture of the orifices in the sac will interrupt the main channel within the strictest minimum space compatible with reliable hemostasis. Those who have had special experience in the technic may, in some cases, find it feasible to resect the anastomotic segment and reunite the artery and the vein by circular suture (Lexer's case). In other cases autogenic or heterogenic grafting or venous transplantation may be indicated when the damaged vascular segment is so large that the

continuity of the vessel cannot be restored by unaided arteriorrhaphy. These later methods, grafting and transplantation (see Treatment of Aneurisms), are simply mentioned because they are suggestive and show the trend of professional aspiration, which is aiming at accomplishing a cure of aneurism by ideal methods—*i. e.*, without interrupting the great avenues of the circulation.

To summarize the principles that should govern the treatment of arteriovenous aneurism:

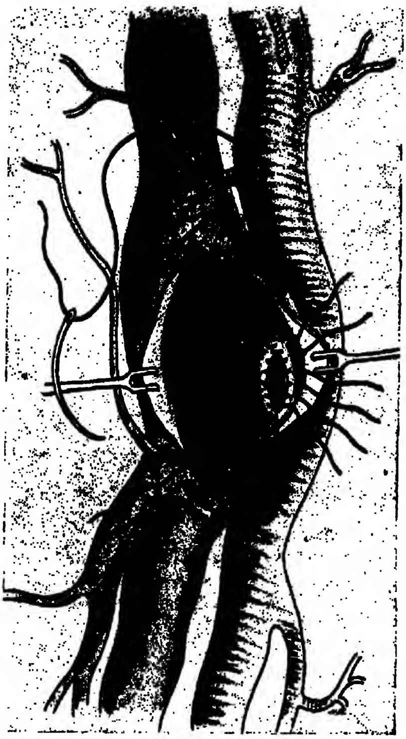

FIG. 103.—ANEURISMAL VARIX TYPE OF ARTERIOVENOUS ANEURISM OF LEFT COMMON FEMORAL ARTERY AND VEIN, SHOWING THE APPLICATION TO THIS CLASS OF ANEURISMS OF THE MATAS METHOD OF OPERATING UPON ORDINARY ANEURISMS.

The opening of the femoral artery into the varicosed vein is shown, with interrupted Lembert gut sutures in position, ready to be tied. The longitudinal incision in the vein or approaching the arteriovenous opening (and which is here made somewhat unnecessarily long) is shown in the act of being closed by two methods of suturing—above, by the continuous Lembert of the outer coats; below, by interrupted ordinary sutures of the outer coats (Bickham, in Ann. of Surg., May, 1904).

(1) Arteriovenous varices (simple aneurismal varices, more especially of the neck and upper extremity) should not be disturbed or interfered with surgically as long as they do not cause annoying or menacing symptoms or functional disability.

(2) Shortly after the injury efforts should be made to favor spontaneous cure by gentle pressure over the anastomosis and on the main artery on the proximal side of the anastomosis (Vanzetti's method), or by simple digital compression of the main artery on the proximal side, rest, and immobilization.

(3) When signs of progressive enlargement of the tumor (in varicose aneurisms) and other objective or subjective evidences indicate that operative interference is required to arrest its progress, that procedure should be preferred as the *method of election* which will obliterate the arteriovenous anastomosis without interrupting the continuity of the parent vessels (endo-aneurismorrhaphy) for varicose aneurisms; incision with lateral arteriorrhaphy and phleborrhaphy for the simple aneurismal varices.

(4) When the damage done to the vessels is so great that the restoration of the lumen is impossible by any of the methods of intrasaccular

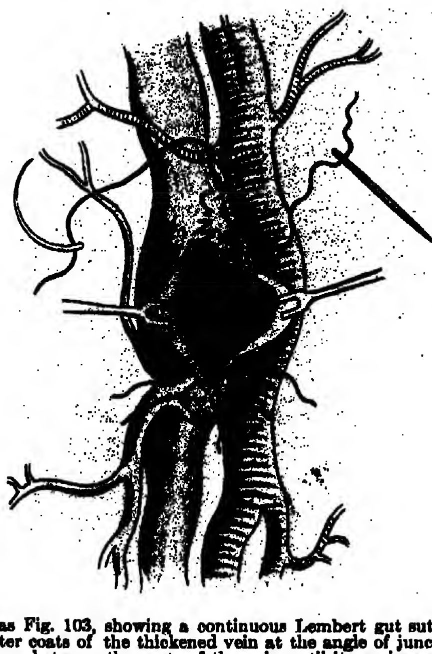

FIG. 104.—Same as Fig. 103, showing a continuous Lembert gut suture, which, having been passed through the outer coats of the thickened vein at the angle of junction of vein and artery and knotted, is passed on between the coats of the vein until its varicosed cavity is entered very near one end of, and immediately above, the first tier of interrupted sutures, and is then made to bury-in this first tier and itself in continuous Lembert fashion and, emerging at the opposite angle of junction of vein and artery, is tied in the same manner as at its entrance; this suture is not yet tightened throughout (Bickham, in Ann. of Surg., May, 1904).

suture (restorative and reconstructive endo-aneurismorrhaphy), obliterative aneurismorrhaphy is to be preferred for old well-formed sacs; the intrasaccular ligature on each side of the vascular orifices (Syme, Annandale, Kikuzi) for recent, thin, and ill-defined sacs and traumatic pulsating hematomata.

(5) In some aneurismal varices, which are embedded in masses of cicatricial or fibrous tissue too dense to permit of a clean dissection of the vessels entering into the anastomosis, resection of the anastomosis may be necessary, with ligation of the afferent and efferent trunks. In such cases an effort should always be made to restore the continuity of the vessels or of the artery, at least, by circular or end-to-end suture. If the operator feels himself competent to try transplantation

or grafting, he should not sacrifice the satellite vein, even if this is available, but secure a segment of a vein from some other region of the body (saphenous, basilic, cephalic, external jugular).

While I realize that the methods of surgical treatment herein advocated are a decided departure from the recommendations of classic authorities (Delbet, Bramann), who advocate as the method of *election* extirpation and the quadruple ligature, I am convinced that the best results will follow the application of the methods of suture which will cure the disease and yet leave the great vascular channels undisturbed. Furthermore, failing to accomplish this, the ligature at the seat of the lesion still remains practicable, therefore, the results

FIG. 105.—VARICOSE ANEURISM OF LEFT COMMON FEMORAL ARTERY AND VEIN, TREATED BY EXCISION OF THE SAC, FOLLOWED BY SUTURING OF THE OPENINGS IN THE VESSELS.

Upon the right, a small elliptic piece of the sac is shown connected with the arterial opening, with the first tier of interrupted Lembert gut sutures in position, ready to be tied. Upon the left, a similar elliptic piece of sac has been left connected with the venous opening. The first row of Lembert sutures has been tied, and a second tier of ordinary sutures through all the coats is being applied, burying-in the first tier. Fig. 105 is the same as Fig. 102, with the sac excised (Bickham, in Ann. of Surg., May, 1904).

cannot be made worse than those of ligation, which is followed by peripheral gangrene in the lower extremities in at least 6 per cent. of the cases (5.66 per cent., Delbet). At one time, and not long ago, it would have been premature and injudicious to insist upon other than ligature methods; the time has now come when the suture of arterial wounds or vascular injuries in aneurismal sacs has ceased to be a mere laboratory experiment, and when this procedure can be confidently expected from any intelligent well-trained surgical practitioner.

Addenda to the Treatment of Arteriovenous Aneurism.—Barring coagulating injections, galvanopuncture, acupressure, forcipressure, etc., as unsurgical and

dangerous, there are several methods in addition to those previously described which claim a place, though quite secondary, in the surgical therapy of arteriovenous aneurisms. These may be classed as follows: (1) Bloodless methods: direct and indirect compression, including simple indirect digital compression, flexion, elastic compression, and Vanzetti's method of combined direct and indirect compression; (2) open methods: Verneuil described no less than eight methods of ligature, extirpation, etc., described in the section on Treatment of Aneurisms. Of the methods of compression, the only one which deserves to be retained in exceptionally favorable circumstances is the combined direct and indirect method, suggested by Guattani (1771) and systematized by Vanzetti (1863). Vanzetti directs that digital compression be applied to the main artery on the proximal side of the sac, while the fingers of the other hand compress the vein at the anastomotic orifice or as near to it as possible. The object of the pressure is to arrest the circulation in the main artery while stopping all flow through the anastomotic channel, aiming at the same time to induce *plastic* adhesion and obliteration of the channel by the irritant effect of persistent compression. Vanzetti cured two aneurisms by this procedure in six hours each; other cases took longer, forty-eight hours, and others still longer. In adopting intermittent compression, three, six, or more sittings may be required before the thrill and pulsation can be made to disappear. Cures can be expected by this method in recent cases only, not later than two or three months after the injury (Delbet). Furthermore, the method is not free from risk of peripheral gangrene. It may excite phlebitis and thrombosis with the attendant danger of embolism. The artery is also known to have undergone repeated aneurismal dilatation after this procedure, in consequence of trauma, and rupture has followed or been threatened, thus precipitating an unexpected operation. According to Delbet, 32 per cent. of the cases are cured if taken at an early stage. Brasseur (Thèse de Paris, 1905) has collected 75 cases treated by this method, of which 26 were cured. In 40 cases at the bend of the elbow, it cured 24 and failed in 16; in the axillary, popliteal, and groin it failed altogether, and succeeded only twice in 11 femoral aneurisms to which it was applied. Therefore, if statistical experience is to be relied on, Vanzetti's method could only be expected to effect a cure in arteriovenous aneurisms of the bend of the elbow, where it will cure over 50 per cent. of the cases. However, it is well worth remembering in the treatment of all recent cases in which the circulation in the anastomosis can be absolutely controlled by this method. The proximal ligature, which has probably been more extensively applied than any other method, has been shown to be not only theoretically unreliable as a method of cure but also more liable to produce peripheral gangrene than any other method. It is condemned by the statistics even of the present aseptic period, as shown by Stimson, Michaux, Curtis, Delbet, Brasseur, and von Bramann. The statistics of the ligature in the modern period are not more encouraging, if we are to judge by Stevenson's report of the South African War: 63 cases of traumatic aneurism, of which 45 were of the diffuse and 13 of the circumscribed variety. Of these, 33 (nearly 58 per cent.) were arteriovenous; 27 of these were treated by ligature and one by primary amputation; 9 of the ligated cases were followed by gangrene (nearly 33 per cent.), compelling amputation.

Of all the operative methods heretofore offered, extirpation of the sac of aneurismal varix has yielded apparently the best results, except, possibly, the intrasaccular ligatures of Kikuzi, who states that he has had but 1 gangrene in his whole experience with 85 aneurisms; and this happened to be an arteriovenous femoral aneurism, in which he ligated the vein. Saigo operated upon 15 arteriovenous aneurisms, chiefly by extirpation, and had gangrene in 1 treated by this method and 1 after the "quadruple" ligature of the femoral vessels. In 36 cases of extirpation from the modern period, collected by Brasseur (1905), there was 1 death, and no gangrene.

mentioned. These are, however, largely selected cases from the literature, and not altogether fair for comparative purposes. Delbet admits, however, that in 53 arteriovenous cases treated by the quadruple ligature there were 3 gangrenes, or 6.66 per cent., which he estimates is four times less than gangrene that follows the simple proximal ligation on the Hunterian plan. While these three modes of treatment—"quadruple ligation," "incision," and "extirpation"—all exclude about the same length of the vascular tract in the artery and vein, they all stand on the same plane as regards the liability to gangrene. However, the traumatism of extirpation is so much greater than the plain intrasaccular ligature or suture (which respects the sac), that there must be greater risk from injury to the regional collaterals whenever extensive extirpations are attempted.

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Note.—The bibliography here given simply refers to publications not included in the bibliography of other sections in the chapter on the Surgery of the Vascular System.

ANEURISMS OF SPECIAL ARTERIES.

The Aorta.—We shall only briefly consider in this section the general results obtained by the operative treatment of aortic aneurisms. The medical, symptomatic, palliative, and other methods of treatment, except the operative, have been sufficiently considered

in the General Treatment of Aneurism, as the remarks there made refer almost exclusively to aortic aneurism.

Before reviewing the surgical (open) treatment of aortic aneurisms it will be well to present a few facts of preliminary interest regarding abdominal aortic aneurisms, as these are more liable, at present, to direct surgical intervention than the thoracic aneurisms. (1) The incidence of abdominal aortic aneurism varies considerably in different parts of the world. (2) Aneurism of the abdominal aorta occurs much less frequently than aneurism of the thoracic aorta; 1: 7, in London, St. Bartholomew's Hospital; to 1: 4, in St. George's, and 1: 2, in New Orleans Charity Hospital. (3) Aneurism of the abdominal aorta occurs most frequently in the prime of life; (4) the disease is 11 times more frequent in men than in women; (5) it is improbable that hard work, apart from sudden effort, is capable of producing aneurism of the abdominal aorta; (6) aneurisms of the abdominal aorta, attributed to strains, are probably due to a rise of blood-pressure caused by a sudden violent effort; (7) chronic intoxications are capable of producing aneurism of the abdominal aorta only by directly causing disease of the aortic walls; (8) in some cases aneurism is due to congenital defects, dystrophy of the media in the vessel-wall; (9) aneurism of the abdominal aorta occurs most frequently in the neighborhood of the celiac axis; (10) it is commonly of the saccular type, and frequently becomes diffuse; (11) the majority of cases terminate by rupture, this rupture being into the retroperitoneal tissues more frequently than elsewhere; (12) they terminate by rupture much more frequently than do cases of aneurism of the thoracic aorta; (13) gastro-intestinal symptoms are not especially associated with aneurism of any particular part of the abdominal aorta; (14) examination with the Roentgen rays would seem to be valuable only as a means of confirming a positive diagnosis; (15) the average course of the disease extends over from thirteen to fifteen months.

Open Surgical Treatment.—*Ligature.*—Abdominal Aorta.—The literature of this great vessel has been recently enriched by the learned and patient researches of M. Katzenstein, and the still later and most thorough monograph of Offergeld. In his very noteworthy contribution Offergeld not only confirms the results of Katzenstein's previous investigations, but, by his experimental study of the blood-pressure after the ligation of the aorta and great arteries, shows convincingly that the reëstablishment of the (collateral) circulation after the ligation of the large vascular trunks is dependent upon a great increase in the blood-pressure above the ligature, and in the suppressed vascular territory. If the heart fails to respond to the strain put upon it, death occurs from cardiac dilatation and insufficiency, and the collateral circulation is not developed. As the result of his study he concludes: that the ligature of the abdominal aorta below the origin of the inferior mesenteric artery taxes the heart with so enormous an amount of work that only an absolutely

healthy and functionally capable organ outlives the strain—a requirement that is rarely met unless it be in acute traumatic hemorrhage directly from wounds of the aorta or its branches in otherwise normal subjects. Death after aortic ligation is ultimately due to failure of heart power. The few isolated instances in which animals have survived the ligature show, by an immense concentric hypertrophy of the organ, that the heart has risen to the full measure of the enormous tax put upon it. If the heart can survive the strain put upon it, the collateral circulation will ultimately develop. The paraplegia observed after aortic ligation is not due to central spinal lesions, as claimed by Sarlo and others, but solely to peripheral ischemia.

The abdominal aorta has been ligated 15 times since Sir Astley Cooper performed the first operation in 1817. Death followed in each instance, though the end was delayed to the forty-eighth day in Keen's case, and to the thirty-fourth day in Tillaux's case. If the patient survives the cardiac strain (which is even rare in perfectly normal healthy animals), he still has to face the risk of rupture or ulceration of the aorta at the seat of ligature with fatal hemorrhage. Shock, hemorrhage, sepsis, but, above all, cardiac and circulatory insufficiency, are the cause of death after this ligature. Keen states that after he had felt "the enormous rebound of the aorta in the narrow ligature we put on these vessels, he made up his mind that never again would he be tempted to tie the aorta in that way"; and accordingly he devised an instrument for the purpose of its obliteration—not by a narrow ligature, but by a broad metal clamp, one clamp behind the artery and the other in front of it, and adjustable by a screw. Lambotte has devised a clamp for the same purpose.

The fact that the blood-pressure is not so high and the heart muscle is able to survive the strain of *partial, gradual* aortic stenosis, as shown by numerous cases (see Tillaux's and Riche's report) in which pathologic occlusion by thrombus and other causes, as shown by postmortem examinations, and that the (collateral) circulation is reëstablished, if the patient survives long enough, encourages the possibility of better results in abdominal and low thoracic aneurisms by the use of the aluminum bands devised by Halsted or its modification by myself. The experimental results obtained by this method are sufficiently encouraging to foster the hope that their further application in practice will yield far better results than have been hitherto obtained by the ligature or any other method of treatment thus far suggested. These and the similar efforts of Stratton, of Oakland, Cal., to cure abdominal aortic aneurisms by *gradual*, direct arterial closure with a specially devised snare-like compressing apparatus, are in the right direction and are preparing the way for final success by gradual occlusion. In addition to the ligature, three attempts have been made to cure abdominal aneurism by the method of intra-saccular suture (Matas) (Losano, of Saragossa, 1905; Munro, of Boston, 1906; Crile, of Cleveland, Ohio, 1907). The conditions were extremely unfavorable for any operation. The arterial orifices leading to the sac

were obliterated by suture; but in two cases hemostatic clamps had to be left *in situ* to control bleeding; in one case from ruptured diverticula (Munro), in the other by the repeated perforation of the atheromatous aorta with calcareous spiculæ and sharp fragments, wherever the clamps were applied on the vessel to control the circulation while the operation on the aneurism was in progress (Lozano). In Crile's case a formidable hemorrhage came from the collaterals in the distal end of the sac, which he thinks could have been prevented by peripheral compression. In suitable cases, as recognized by preliminary exploration, in which a typical sacciform aneurism with a single orifice of communication is found, it may be possible to obliterate the sac without interrupting the continuity of the aorta. In fusiform aneurisms above the renal arteries, and all those in which free access and control of the circulation in the sac are not easily obtained, the operation of endo-aneurismorrhaphy, as well as the ligature or any other obliterative procedure by direct intervention, is contraindicated.

Ligatures in the Treatment of Thoracic Aneurisms.—Permanent Ligation of the Thoracic Aorta Below the Left End of the Arch (Brasdor Principle).—Guinard, Paris, performed this operation for the first time in surgical history on June 20, 1904. The aorta was reached by a posterior thoracostomy and osteoplastic flap. As the ligature was drawn tight, the femoral pulse stopped at once, and the lower part of the body grew pale and cold, but in less than fifteen minutes the circulation became reëstablished and the parts grew warm again. After the ligature of the aorta in the thorax the intercostal anastomoses were sufficient to supply the abdominal aorta and the legs with blood, but the physiologic functions of the kidney, requiring a considerable degree of blood-pressure in the renal arteries, were totally arrested by the reduction in the intra-arterial pressure. This is an additional reason why ligature of the aorta above the renal arteries proves invariably fatal.

With the object of removing an aneurismal sac which he believed to be accessible and amenable to extirpation, Tuffier, Paris, applied a ligature not to the pedicle, but near the summit of a saccular aneurism of the arch, 3½ cm. from the neck. The sac was not resected, becoming gangrenous on the fourteenth day, and the patient died from secondary hemorrhage on the seventeenth. As far as is known this case is unique in literature.

Temporary Ligature of the Thoracic Aorta.—This has been unsuccessfully attempted by Tormi (Buenos Aires) and Villar (Bordeaux). (See Boinet, "Maladies des Artères et de l'Aorte," Brouardel-Gilbert, Nouveau Traité de Méd., Paris, 1907.)

Ligature of the Iliacs.—This is an application of the Brasdor and Wardrop method to aneurisms of the abdominal aorta. This ligature below the sac has invariably proved fatal.

The *ligation of the peripheral arteries—on the Brasdor-Wardrop principle for the cure of aneurisms of the arch of the aorta* has been studied by many authors, among them Rosenstirn (Arch. klin. Chir.,

1887, Bd. xxxiv), Jacob (Inaug. Dissert., Berlin, 1892), Jacobsthal (Deutsch. Zeit. Chir., Bd. lxiii, 1902). In France, where this method of treatment has received special attention, in consequence of the influential advocacy of Guinard and Le Dentu, the statistics of Acosta Ortiz (Thèse de Paris, 1892), Poivet (Thèse de Paris, 1893), of Blacque (Thèse de Paris, 1895), and the recent paper by Guinard (Revue de Chir., February 10, 1909), are especially important. In the United States Randolph Winslow's paper (Annals of Surgery, May, 1891) is also to be consulted. The procedures which have been applied for the purpose of curing, not only aneurisms of the aorta, but also of the innominate and those of its branches at their origin in the mediastinum, because they all merge one into the other and are very difficult to isolate as separate aneurisms, may be grouped as follows: (1) Ligature of the left common carotid; (2) ligature of the right common carotid; (3) simultaneous ligatures of the right common carotid and the right subclavian; (4) ligature in two sittings of the right common carotid and the right subclavian; (5) ligature of the left common carotid and the left subclavian; (6) simultaneous ligature of the left common carotid and the left axillary; (7) simultaneous ligature of the left common carotid and the left subclavian.

Jacobsthal, in reviewing the statistical evidence which had accumulated up to 1903, found a total of 44 reported cases in which the procedures above mentioned had been applied. He concluded that the immediate operative recoveries, with the reported cures or marked improvement, may be estimated in the later statistics to be 66.7 per cent.; with the old and the modern combined, 53.5 per cent. Of the 23 reported recoveries, 15 were observed until death, but only 3 cases survived at least three years. It follows that, notwithstanding the high percentage of reputed operative cures, the favorable results are found to be very modest on closer inspection, especially when the fact is taken into consideration that the natural duration of the disease is not always a short one—*e. g.*, in Whipham's case the patient survived sixteen years after the recognition of the disease and without any operative treatment.

Guinard, whose experience (15 personal operations) entitles his opinion to the highest consideration, expresses himself as well satisfied with the results of these ligatures. He especially recommends the simultaneous ligation of the common carotid and the subclavian on the right side, an operation which he first performed in 1892, and is known by some operators as Guinard's procedure. He insists emphatically upon the ligation of the common carotid as the first part of the procedure. Silk or catgut can be used; drainage is not necessary unless the operation has been particularly long and difficult. The results are better the greater the distance between the aneurism and the heart; his experience teaches him that whether the aneurism begins in the arch of the aorta or in the innominate, or in the branches given off by this trunk, the simultaneous distal ligation of the common carotid and the right subclavian will be followed by beneficial results.

His later experience warrants him in saying that in every case some benefit may be expected.

As a whole, we are inclined to conclude with Boinet that these various ligatures have furnished only mediocre results, with short survivals and temporary improvements; they constitute procedures of necessity, and are to be employed in those cases in which medical means have proved inefficient, or where the constant growth of the aneurism threatens the patient's existence.

Innominate aneurism represents 3 per cent. of all internal aneurisms. Though the innominate artery is a comparatively short tract, the aneurisms which develop at its expense are susceptible of division into at least four types, which it is important to distinguish for diagnostic and surgical purposes: (1) Some are situated at the origin of the vessel, the innominate sac blending with the aortic arch; (2) others occupy the terminal portion of the artery, and involve either the carotid, the subclavian, or both vessels, in the sac. Next to the first group, this is the most common form and the most important for the proximal ligature or Halsted's bands, or the intrasaccular suture. (3) Sometimes the entire circumference of the artery is involved, forming a true fusiform aneurism. (4) In the rarest group, the dilatation remains limited to the middle portion of the artery (Whipham and Whiting's cases).

Innominate aneurisms are usually of the saccular type. The fusiform variety is rare. Some of the largest known aneurisms have sprung from the innominate. In their development they present two phases: the intrathoracic and the extrathoracic or cervical. In adapting itself to its environment, the sac sometimes assumes a bilobular appearance. In one case the sac extended from the sternal notch to the epigastrium (Hampeis; Delbet). Participation of the subclavian in aneurisms of the innominate is by no means rare—17 per cent. (Poivet), 21.4 per cent. (Jacobsthal). The prognosis and the treatment in these mixed cases coincide with those of innominate aneurism.

The differential diagnosis of these aneurisms from those of the aortic arch or the mixed aortic-innominate and the simple innominate, is far from easy, and from the surgical point of view unimportant; however, great assistance is obtained in obscure cases by careful and repeated fluoroscopic examinations.

Treatment.—The medicinal treatment is the same as that applied to aortic aneurism. Excluding wiring (Moore's method) and the Moore-Corradi method, needling and simple galvanopunctures, the only surgical treatment thus far applied has been limited to the ligature. The proximal ligature between the aneurism and the aorta has been applied in all only 6 times.

According to statistics, the involvement of the aorta with the innominate does not constitute a contra-indication to peripheral ligature of the subclavian or carotids. The prognosis as to permanent results in these mixed cases is unfavorable. Of the 120 known

of the mixed type operated upon by peripheral ligature, Jacobsthal knows of only two which have lived for more than three years after the operation.

Aneurisms which are confined to the innominate are most benefited by the distal ligature, the saccular variety being more favorable than the fusiform, and the small size than the large. Fortunately, the diagnosis of the seat and extent of the aneurism, and especially of the extent of aortic involvement, which formerly it was frequently impossible to determine and gave rise to numerous mistakes, has been remarkably cleared and facilitated by the x-ray and fluoroscopic examinations. L. Imbert and H. Pons (Arch. Provincial. Chirurgie, T. xvii, 1907), in a very complete review of the subject, agree with Guinard and Le Dentu in the decided possibility of curing innominate aneurism by distal ligation, and that the method of election is the simultaneous ligature of the right common carotid and right subclavian, beginning always with the common carotid. They do not dread cerebral complications after the ligature of the common carotid, provided the opposite carotid is not obliterated. Obliteration is recognized by the absence of the temporal, facial, and carotid pulse. Under these circumstances the right subclavian alone could be ligated, provided, again, that the corresponding radial pulse is felt. The results thus far obtained are: operative deaths, due to secondary hemorrhage and cerebral complications, 15 per cent.; failures to influence the growth of the aneurism, 30 per cent.; apparent permanent symptomatic cures, 22 per cent. Seemingly, therefore, one-fourth of the cases should be benefited by this procedure.

The innominate artery was ligated for the first time by Valentine Mott, of New York, on May 11, 1818, for traumatic subclavian aneurism. The patient died on the twenty-sixth day from sepsis and secondary hemorrhage. The first successful operation was performed by Andrew W. Smyth at the Charity Hospital, New Orleans, La., May 15, 1864, for a subclavian aneurism. In this case the innominate, carotid, and vertebral were ligated for the first time. Septic infection and secondary hemorrhage occurred, as usual in those days, on the fifty-fourth day, when the vertebral was ligated, the hemorrhage being controlled to some extent by the ingenious expedient of the operator, who filled the wound with shot. The patient left the hospital apparently cured, but returned in 1875 with the aneurism as large as before; the internal mammary was ligated without benefit; the sac, threatening to burst, was opened by direct incision, with the hope of plugging the opening of the aneurismal artery, but in vain. The sac had to be plugged en masse, and the patient died of hemorrhage within forty-eight hours.

The most recent statistics of ligature of the innominate are: Jacobsthal (Deutsch. Zeit. f. Chir., lxiii, 1902); Delaup, New Orleans (Phil. Med. Jour., January 26, 1901); Sheen, of Cardiff (Annals Surg., January, 1905), and Burns, of Memphis (Trans. Surg. Sect. Am. Med. Assn., June, 1908). Burns, in his summary, shows that of the 51 times the innominate artery has been approached with the idea of securing it in a

ligature, 11, or 21.5 per cent., recovered; 21, or 42 per cent., suffered from wound infection; 6, or 11.6 per cent., died from shock, and 6 died of cerebral complications. Out of the total 11 recoveries, 36 per cent. of the wounds were infected.

Carotid Aneurisms.—I. Common Carotid Aneurisms.—Aneurisms of the trunk are more frequent than that of its branches. Their relative frequency, compared with other aneurisms, is 25: 551 (Crisp); 5: 172 (Holcombe). Aneurism, which in general is a rare disease in women, is relatively frequent in the carotid region. Aneurisms of other arteries occur 8 times more often in men than in women, but in the carotid region one-third of the cases occur in women. According to Guyon, the arterial tension is enormously increased during the expulsive efforts of labor, and the carotid is then likely to be strained or overstretched by compression against the lateral lobes of the thyroid, which is also enlarged in pregnancy. Carotid aneurisms almost always originate on a pathologic or arteriosclerotic base. The pure traumatic aneurisms are rare, except perhaps as arteriovenous aneurisms resulting chiefly from gunshot wounds, but even in these circumstances they are not frequent, at least among those who survive the injuries of the battle-field. Thus, Kikuzi reports only one common carotid and two external carotid aneurisms in his whole collection of 85 aneurisms treated in the Russo-Japanese war; Saigo mentions no carotid aneurisms in his table of 36 cases.

It has been observed at all ages, but it is usually a disease of advanced adult life (forty to fifty years).

Aneurisms may develop in any part of the course of either carotid, but the favorite localities or points of election are: at the origin, on the right side, where the carotid is given off from the innominate; and on the left, where it arises from the aortic arch; then where the artery bifurcates into its internal and external branches. Whether the aneurisms develop with greater frequency at the origin of the carotid (Robert) or at its termination (Hodgson) is of no great consequence, but what is really important is that the aneurisms which develop at these two extremes are fundamentally different in their symptomatology, clinical history, prognosis, and, above all, their treatment. Statistically speaking, the right carotid is more frequently the seat of aneurism than the left, but this applies only to aneurisms of the intrathoracic portion, and even here it is possible that innominate aneurisms may have been included with those of the carotid by errors of diagnosis.

Carotid aneurisms are usually of small size; they are more often ovoid in form, their long axis lying parallel to that of the vessel. They usually develop from below upward. In only two cases (Syme, Sorrentino) do the sacs appear to have developed from above downward, *i. e.*, from the neck into the thorax. It is also very exceptional to see a carotid aneurism cross the median line to the opposite side, and in only two cases has this unusual development been recorded (Decés and Sorrentino). The important relations of the artery to its surroundings readily account for the pressure signs and the classic

modes of termination. On the inner side, the trachea, larynx, esophagus, and pharynx are readily compressed, displaced, obstructed, and offer good opportunities for the rupture of carotid aneurisms. The pneumogastric, phrenic, sympathetic, laryngeal recurrent, branches of the brachial and cervical plexuses, and the internal jugular vein, all become intimately blended with the carotid sheath and ultimately with the aneurismal sac, in this way contributing to the difficulties of extirpation or even ligation, when this is attempted in low intrathoracic aneurisms.

Treatment.—The older literature of the last century shows that the methods of Valsalva and Tuffnell have cured a few cases (J. L. Petit, Dupuytren, Huker). A most remarkable case of this kind is mentioned by Ciniselli, who saw a patient thirty-five years after he had been cured in this way by Solizolli. The patient had had the fortitude and the courage to remain quietly in bed eleven months, during which he ate only a little bread and a few swallows of broth. At the close of this treatment he was frightfully emaciated. The aneurism, which was cured at the cost of this immense physical sacrifice, was not larger than a small nut. Coagulating injections, galvanopuncture, malaxation, direct compression, have all been tried, and have all contributed to increase the mortality of this formidable type of aneurism, in which one of the chief dangers lies in the tendency to the fatal liberation of emboli and thrombi in the brain. Proximal digital compression, with the finger over the artery at Chassaignac's tubercle, or by pinching the artery through the substance of the sternomastoid between the thumb and the index-finger (Rouge's method), has been applied in a few favorable cases of high carotid aneurism, in which the artery can be compressed below its lower pole. The statistics of this method are particularly unreliable, as it is impossible to estimate the number of times in which digital compression has been applied and failed, the few successes alone being published. Delbet mentions five cases in which he knows that this method has been systematically applied for therapeutic purposes, with three recoveries. It is a dangerous method, because all methods which cause intermittent stasis in the sac favor the liberation of emboli which lodge in the brain.

Operative Methods.—The methods of treatment which at present claim the attention of the profession in the treatment of carotid aneurism are: (1) the proximal ligature (Anel), whenever there is sufficient space between the origin of the vessel and the aneurism to permit of its application; (2) distal or peripheral ligation (Brasdor) in low intrathoracic non-pedunculated aneurisms; (3) incision with double ligature (Antyllus); (4) extirpation (Philagrius); (5) Halsted's method of gradual obliteration with metallic bands, or their modifications by Matas, and (6) endo-aneurismorrhaphy in any one of its three forms. The selection of the method will depend, at least, upon three conditions: (1) The topography of the aneurism, whether intrathoracic or cervical, whether on the right side the innominate is

involved with the carotid down to the aorta or not, and whether, on the left side, the aorta participates in the carotid enlargement; (2) upon the effect that the method selected will have upon the circulation of the brain; (3) the effect it will have upon the peri-aneurismal adherent structures. From the beginning of carotid surgery to the present time the dread of cerebral disturbances has invested the technically simple operation of ligating the common carotid artery with a gravity and anxiety that are associated with few other ligations. A mere glance at the surgical history of this vessel will show how thoroughly justified surgeons have been in their fears, and why every effort has been made to limit and circumscribe the indications for its performance to the strictest minimum, always preferring to ligate the external carotid whenever the desired results can be accomplished by the obliteration of this relatively innocent branch.

The first records are associated with the names of Hebenstreit and Fleming, 1803, who ligated the artery successfully for hemorrhage, the first while extirpating a cancerous growth, and the second in a case of cut-throat. Abernethy, who is usually credited with the first ligation, operated in 1804 for hemorrhage, also with success. In 1805 Sir Astley Cooper ligated the common carotid for the first time for aneurism, the patient succumbing from hemiplegia on the twenty-first day. He repeated the operation in 1808 for aneurism, dividing the artery between two ligatures. The aneurism was cured and the patient recovered.

The relative frequency with which these cerebral disturbances occur was: 32 per cent., of which 56 per cent. died (Pilz, 1867); 54.5 had cerebral symptoms, of which 39 per cent. died (Le Fort, 1868); 25 per cent. (Reiss, 1885); 20 per cent. (Wyeth, 1878); 26 per cent., with 31 per cent. deaths (Zimmermann, 1885–91); Kraneophul (1901) noted cerebral disturbances in 23.9 per cent.; Schirner (1906), 10.3 per cent.; Lebram (1906), 24.5 per cent., of which 7.1 per cent. developed hemiplegia, and 17.4 per cent. other cerebral disturbances apart from hemiplegia. After subtracting all the complications which are avoidable by asepsis and modern technic, we must admit that the occlusion of the common carotid still remains a dangerous procedure, which we may estimate at one-fifth of the cases with Delbet, or 25 per cent., with the latest estimate of Jordan (Heidelberg, 1907), in which no less than 10 per cent. died. How long after suspension of brain function by acute ischemia following a ligation this function can be restored is still uncertain. Wernicke holds that the actual disintegration of the nervous elements begins thirty-six to forty-eight hours after the arrest of the blood-supply. Bernhardt expresses himself similarly, stating that absolute tissue necrosis may be arrested if the collateral circulation is established within twenty-four or forty-eight hours. Marchand regards the time allowed for restoration of function as considerably shorter, especially as far as the gray matter of the cortex and central ganglia are concerned.

All conditions which delay or inhibit the development of the

carotid circulation favor the occurrence of cerebral complications. The greatest impediment in the way of prompt development of the collateral circulation is arteriosclerosis. Hence, the great danger of this ligature after the fortieth year, as recognized by all experienced operators. In addition to arteriosclerosis, the following conditions may interfere with the development of the collateral circulation: (1) Congenital anomalies of the circle of Willis, and absence of some of the vessels of the brain and head, in 24 per cent. of the cases. (2) Functional and organic diseases of the heart (valvular heart lesions in 2.6 per cent. of all fatal cases). (3) Thrombosis in the ligated vessels, extending to the brain. (4) Emboli, which block the circle of Willis; these may be displaced from the sac of a coagulating aneurism. The essential cause of the cerebral phenomena is ischemia, followed by degenerative changes.

To avoid the evil effects of cerebral ischemia, especially in aged patients, temporary occlusion of the carotid should be tried before attempting an irremediable ligation or extirpation of the diseased artery. This is the teaching of Halsted (1905), Jordan, of Heidelberg (1907), based upon their own experience and upon the evidence of toleration of the carotid for provisional constriction furnished by Singer, Reiss, and especially Crile (1901), who showed that the common carotid may be clamped for forty-eight hours without permanently damaging the artery or causing thrombosis. Adopting Halsted's suggestion of utilizing aluminum bands for this purpose, I resected the entire common carotid and its branches beyond the bifurcation, without complications, in the extirpation of a recurrent carcinoma of the neck, after trying provisional compression forty-eight hours before attempting the radical operation. As no cerebral symptoms developed, the operation was performed with greater confidence in the result; though it must not be forgotten that cerebral symptoms and death may occur one or two weeks after the ligation. Usually, however, a defective circulation is indicated by the prompt, if not immediate, appearance of symptoms after the provisional compression. If symptoms develop, the constricting band can be promptly removed by cutting through the band or by removing the little clip which holds the end of the band together. The preliminary "test constriction" may be applied with the help of local anesthesia (Schleich solution, No. 1 or 2). It is important, in fact, that this preliminary test should always be made with local anesthesia, in order to obtain prompt information of the cerebral effects of the carotid occlusion. The constriction should be made just tight enough to obliterate the lumen of the vessel without injuring the intima.

In the light of this important suggestion the entire surgical treatment of the carotid must now be revised. In future, no one will be justified in planning a deliberate operation for the cure of aneurism in this perilous locality without first testing the efficiency of the collateral circulation. In all aneurisms in which the upper or cephalic end of the sac is at all accessible, a Halsted or Matas band

should be rolled around the artery, or at least around the internal carotid, when the aneurism involves the bifurcation. If no symptoms develop, the ring is clamped tight enough to obliterate the lumen. If the aneurism remains active, in spite of this distal occlusion, a proximal ligature should be applied and the sac extirpated, if it is small, but in *large sacs* with universal adhesions to important organs, veins, and nerves, the sac should be simply incised while its two poles are clamped, evacuated thoroughly, and obliterated by the intra-saccular suture (Matas). In low-lying aneurisms involving the intrathoracic origin of the carotids, inoperable in a radical sense, a Halsted band can be substituted for a distal ligature on the Brasdor plan with a view of relieving the symptoms should they develop. In sacciform aneurisms in which the cardiac end of the aneurism can be controlled for hemostatic purposes, the ideal operation is a restorative endo-aneurismorrhaphy, by which the sac is obliterated without interfering with the lumen of the vessel. The reconstructive operation, which aims at the preservation of the main channel of the circulation, is indicated in those cases in which the preliminary occlusion test shows that the collaterals are inadequate. However, the reconstruction of the carotids out of a fusiform sac is fraught with risk from embolism, and a gradual occlusion with Halsted's aluminum band, applied to the cephalic end of the sac, is preferable. If the sac remains active after this distal obliteration of the artery, then an obliterative endo-aneurismorrhaphy would be in order in preference to extirpation, for the reasons previously given.

Delbet estimates the mortality of the distal ligature, in otherwise inoperable intrathoracic carotid aneurisms, at 45.1 per cent.; the proximal ligature on the Anel plan, in the modern period, and in a comparatively small group of cases, is followed by a mortality of no less than 12 per cent. The mortality, which, in both instances, is attributable to a considerable extent to cerebral complications, should in future be very much diminished by the general adoption of the preliminary test on the Halsted and Jordan plans.

Extirpation.—The statistics of the extirpation of carotid aneurisms are all of comparatively recent date, and much more favorable than those of either the Anel or Hunterian ligations. It is, however, unfair to institute a comparison between ligation and extirpation in the aseptic period, since the number of extirpations is entirely too small to permit of a just estimate of its merits. Delore (Lyons, Revue de Chir., January 10, 1907) has recently tabulated ten cases of extirpation of carotid aneurisms, which have been recorded since Morris' first operation (Morris; Delagenière, 1896; Inouye; Karewski, 1891; Walsham, 1899; La Torre, 1898; Tuffier, 1903; Mendes, 1905; Delorme, 1906). All these recovered except Tuffier's case. Delore, on this basis, estimates a mortality of 10 per cent.; but without any extensive research into the literature, I know of at least 2 cases in which carotid aneurisms were extirpated with fatal results, and no doubt a good many more could be quoted which ended unfavor-

ably, but have not found their way into print. In the presence of cerebral complications, from the mere fact of carotid occlusion, all obliterative measures must yield in adult subjects a mortality of not less than 20 per cent.; in exceptionally favorable groups, possibly 10 per cent. Apart from this, extirpation has the advantage over the proximal ligature, which leaves the distal (cephalic end) open, in being less subject to embolism. It is also less liable to the danger of secondary suppurative infection in the sac itself, a common occurrence after the ligature, especially in the preantiseptic days, the infection spreading from the infected ligature to the sac. It is also superior in the permanency of cure, since relapse is impossible after the extirpation of the sac. On the other hand, extirpation involves very severe traumatisms, especially in old and large sacs, in which the pneumogastric, sympathetic, recurrent laryngeal, and other important structures are likely to be injured. For this reason, in large aneurisms, incision and obliteration by the intrasaccular suture method is a much simpler and safer procedure, and is certain to be followed by less shock and other dangers than either the old Antyllian operation or that of extirpation.

In connection with the extirpation of carotid aneurisms and the possible injury of the internal jugular vein high up in the neck, Rasanoff's recent suggestion in connection with the arrest of hemorrhage of this vessel by temporarily ligating the common carotid is of decided value. In the case of a soldier, whose internal jugular had been cut by a stab in the left side of the neck, he was able to arrest an immense hemorrhage by merely constricting the common carotid in a provisional ligature. The bleeding stopped at once, and the wounded vein was found and secured in a comparatively bloodless field. While in experiments on animals the simple ligature of the common carotid will not stop all jugular bleeding, it will greatly diminish it. Rasanoff's case shows that the temporary compression of the common carotid will act as an efficient hemostatic in difficult hemorrhages of the internal jugular, in which provisional hemostasis is absolutely necessary in order to find the bleeding point.

Internal Carotid Aneurisms.—The aneurisms of the internal carotid present very different characteristics according to their location whether in—(*a*) the cranial portion of the artery or (*b*) in its extracranial portion. Hence the anatomic and clinical division into *intracranial* and *extracranial* carotid aneurisms.

1. The study of the intracranial aneurism is closely identified with the surgical history of pulsating exophthalmos, which is the usual external manifestation of arteriovenous aneurism of the internal carotid within the cavernous sinus. These are fully described in the Surgery of the Head (Vol. III., p. 132).

2. *Extracranial Aneurisms.*—These occur in the internal carotid from its origin to its entrance into the carotid canal. While intracranial carotid aneurisms are reported with comparative frequency (113 in 1000 ligations, Siegrist), those of the external portion are of very rare occurrence, and are seldom reported. Crisp (1844) mentions

only two cases in his collection of 551 aneurisms. It is fortunate that these aneurisms are rare, because when they do occur, they are very often mistaken for other conditions with fatal results; thus, in 11 extracranial aneurisms collected by Werner, only 6 were correctly diagnosticated before treatment. They are most often mistaken for growths projecting into the fauces or for tonsillar abscesses. Duke and Dubreuil also incurred the same error, with unfortunate results. Still rarer are the aneurisms of the vertebral which appear in the same locality. They are differentiated by compressing the carotid over the fifth cervical vertebra (Chassaignac's tubercle), or by pinching the vessel laterally through the sternomastoid between the thumb and index (Rouge's method). If the aneurism is of carotid origin, it will shrink and stop pulsating while the compression lasts. Aneurisms arising in the internal carotid tract are usually readily explored by bimanual or combined extrabuccal and intrabuccal digital exploration.

Etiologically, these aneurisms may be divided into three groups: (1) Traumatic, false aneurisms; (2) erosion aneurisms, caused by ulceration of the internal carotid in peritonsillar and retropharyngeal suppurations; (3) true arteriosclerotic or so-called spontaneous aneurisms. The sheltered, deep, and well-protected position of the internal carotid easily accounts for the rarity of traumatic aneurisms. On the other hand, septic inflammatory processes beginning in the tonsil and the palate are the most frequent cause in the upper half of this tract, not only by erosion but also occasionally by accidental puncture of the artery made by the surgeon while evacuating tonsillar and palatine suppurations. The lower third of the artery is the most exposed to external trauma.

Aneurisms may develop in any part of the artery, but the favorite seat of the spontaneous variety is in the normal bulbous dilatation and its origin at the bifurcation, the curve formed by the artery at this point favoring arteriosclerotic processes and secondary dilatations, as in other parts of the body when arteries become tortuous or curved in their course. When aneurisms form in any part of the artery, they meet the resistance of the vertebral column posteriorly, and consequently developing in the line of least resistance, expand forward into the palatine, tonsillar, or retropharyngeal region; or extend laterally between the mastoid and the angle of the jaw.

In the treatment of these aneurisms the same risk of cerebral complications which attends the ligation of the common carotid must be reckoned with, hence the same precautions which have been recommended in discussing the treatment of common carotid aneurisms apply here with equal force. The efficiency of endocranial and cervical collaterals should always be tested as a preliminary to ligation by a period of preliminary compression with a small clamp or modified Halsted band. In low-lying aneurisms involving the origin of the vessel the band, clamp, or ligature should be applied on the common carotid at the seat of election, that is, when it is impossible to reach

the internal carotid on the distal side, between the cranium and the sac. In aneurisms which leave a free space between the sac and the bifurcation a band should be applied on the vessel above the bifurcation. If cerebral symptoms develop, the band or clamp should be removed. If the occlusion is well tolerated, the band should remain, the aseptic pack be removed, and the wound be closed.

The internal carotid was first ligated by Gurdon Buck, of New York (Amer. Jour. Med. Sci., 1850, vol. xxxi.) simultaneously with the common carotid, for a wound in the parotid region. Velpeau (Méd. Op., vol. ii.) also ligated the internal carotid and the external from a wound in the neck. Wood, of New York (1847), also ligated both the internal and common carotid for aneurism of the external carotid (N. Y. Jour. Med., 1857). Keith, who is often credited with the first ligation, tied the internal carotid for a hemorrhage of this vessel caused by swallowing a pin which perforated the artery. (For historic references, see L. Lefort, Dict. Dechambre, article "Carotid." According to the latest contributor to this subject, Bobbio (Il Policlinico, February, 1906, vol. xiii., C.), the common trunk has been ligated eleven times in 18 cases of aneurism of the internal carotid, with six recoveries. In all acute traumatisms or emergencies, such as in accidental puncture of the carotid while opening tonsillar or pharyngeal abscesses, the common carotid should be immediately exposed and provisionally compressed with a traction loop or clamp, thus controlling the bleeding, while a search is made for the bleeding point. If the ligation of the artery at the seat of injury is impracticable, the common carotid should be tied together with the external carotid, and the superior thyroid, as Wyeth did successfully in a case of aneurism of this artery. If it is possible, however, the ligature should be applied on the internal carotid itself at a distance from the bifurcation in order to help the collateral circulation as much as possible through the external carotid.

In relapsing aneurisms which return in spite of the ligation of the internal carotid, extirpation, or preferably *obliterative* endoaneurismorrhaphy, may be contemplated, provided it is possible to to secure the upper as well as the lower pole of the sac for hemostatic purposes. In order to reach the sac the usual technic required to extirpate retropharyngeal neoplasms by the cervical route will have to be adopted, including temporary resection of the lower jaw in order to give free access to the upper prevertebral region. There is no doubt that in these cases endo-aneurismorrhaphy limited to the suture of the orifices, with packing of the cavity in irregular large sacs, will be safer than a complete extirpation, which might involve the lower cranial nerves at their exit from the cranium and the bulb of the jugular vein, which, in this locality, is a formidable bleeder and difficult to control. The further study of the peculiarities of internal carotid aneurisms can be profitably pursued by consulting Werner (loc. cit.); Bobbio and Blauel (Beiträg. klin. Chir., Bd. xxxix., Heft 3).

The External Carotid Aneurisms.—Aneurisms of the external carotid are even less frequent than those of the internal branch. Aneurisms of the eight individual branches of the external carotid are, however, not rare, as shown by the considerable literature in the Index Catalogue of the Surgeon General's Library (first and second series). The external carotid was first ligated for a nevus of the face by Wurtzer, of Bonn, in 1841, and for aneurism by Richard, of Paris, 1855, as stated by Broca, who assisted at the operation (Traité des anevrismes). This artery had been ligated for traumatism by other surgeons long before, viz.: Bush, of Chatam, England, 1827; Scott, of London, as a preliminary hemostatic in resecting the upper jaw, 1830; and also by Lizars, of Edinburgh, for the same purpose the same year. Maisonneuve ligated the external carotid ten times for various purposes, and for the first time to starve a malignant growth. Delbet collected (1889–95) 11 cases of aneurisms of the external carotid treated by ligature of the common trunk, with 5 cures and 3 deaths, one of these caused by embolism of the Sylvian artery. In 3 the aneurism persisted; one of these was subsequently cured by extirpation and the other by incision. The external carotid was ligated only once for aneurism of its own trunk; secondary hemorrhage occurred, compelling the ligation of both common carotids, the patient dying ultimately from pyemia. It is evident, from Delbet's statistics, that the methods of attacking aneurisms of this artery by ligature must be revised. If the aneurism involves the origin of the vessel at the bifurcation and is large, obliterative endo-aneurismorrhaphy should be performed, preceded by provisional occlusion of the common carotid with a clamp. The smaller aneurisms with unimportant relations should be extirpated. In aneurisms of the branches, after securing temporary hemostasis by clamping the common carotid, the sac should be extirpated if small, or opened and obliterated by the intrasaccular method if larger and adherent to important parts, as in cases in which the tumor lies imbedded in the parotid (temporomaxillary aneurisms), in which even free incision of the sac may involve the facial nerve and the salivary ducts. In a traumatic aneurism of the parotid region Nuvoli (quoted by Delbet) ligated the external carotid, superior thyroid, lingual, facial, occipital, and temporal. "After this veritable orgie of ligatures," success finally crowned the operator's efforts. It is evident that in some of these difficult aneurisms, awkwardly placed for direct or radical intervention, the external carotid could be obliterated as a whole by injecting paraffin into the vessel by the method of Dawbarn and Wyeth, which is equivalent to the extirpation of the external carotid and all its branches. This should prove more efficient and thorough than any other method of extirpation of the parent vessel, apart from the obliteration of the sac itself. For the literature of plugging the external carotid with paraffin, see Dawbarn's Gross prize essay, 1903.

In 1874 Madelung tabulated all the cases of ligation of the external carotid, in which he records 32 deaths in a total of 130 cases of this

ligation, 13 of which were bilateral. At present, since the adoption of modern aseptic methods, it would be impossible to tabulate the statistics of external carotid ligations so as adequately to represent the actual mortality. While the ligation in itself is inherently a perfectly safe and benign procedure, practically devoid of all risks when infection is excluded, it is, nevertheless, liable to complications and even fatal cerebral disturbances in the most aseptic cases *whenever the ligature is placed too near the bifurcation.* When this is done emboli may be swept through the internal carotid into the brain, giving rise to hemiplegias, as has happened three times in my own practice, including 65 ligations for the starvation of malignant growths, and especially for prophylactic hemostasis, while operating on tumors in the territory of the artery.

Subclavian Aneurisms.—Aneurisms of the subclavian artery are nearly as frequent as those of the carotid. Of 551 aneurisms in general, 20 were of the innominate, 23 of the subclavian, and 25 of the carotid. Only 6 per cent. of the patients were women. These aneurisms are more frequent on the right side (66 per cent.) in 120 observations; aneurisms on both sides were observed in 2 cases. The spontaneous or idiopathic are 6 times more frequent than the traumatic. In 115 cases studied by Souchon, 31 were traumatic and 81 idiopathic aneurisms. Of the 81 idiopathic aneurisms, 57 were right sided and 24 left sided.

Aneurisms of the third division are far more frequent than those of the first and second. The aneurisms of the first division in 17 to 21.4 per cent. fuse with the innominate artery, forming subclavio-innominate aneurisms. The symptomatology, prognosis, and treatment of this artery are identical with those of the aneurisms of the innominate group. In another and more frequent variety, in the third portion of the subclavian, they blend with the axillary (subclavio-axillary aneurism). In connection with three aneurisms of the third division, cervical ribs have been reported which predisposed to injury of the artery. Aneurisms of the third division tend to extend downward under the clavicle toward the axilla. Usually they are globular in shape and are not large, but sometimes they may attain enormous proportions. In a classic case (Velpeau) the aneurism filled the axilla, the entire supraclavicular fossa, and the right half of the neck, extending up as high as the angle of the jaw and backward beyond the tips of the transverse processes.

The **symptomatology** and **diagnosis** are made easy by the study of the anatomic relations of the artery. Pressure phenomena are shown conspicuously in the dilated veins, dusky and livid skin, edema of the neck and arm, neuralgias of the neck and arm, gradually followed by paresis or paralysis, in this way resembling the clinical features of axillary aneurisms.

Prognosis.—Subclavian aneurisms do not tend to spontaneous recovery. Poland has recorded 4, Poinsot, 8, and Wyeth, 11 cases cured without operation. The course of the disease, untrammeled

by surgical treatment, was studied by Poinsot in 11 cases. In one the aneurism lasted eight years; in another, two years and eight months. The remaining 9 succumbed within a period varying from five months to two years. The tendency is constantly toward rupture, which usually takes place externally, though it may occur into the trachea, bronchus, or pleura.

Treatment.—Every imaginable remedy ever suggested for the cure of aneurisms in general has been tried in the treatment of the subclavian variety; all the non-surgical methods recommended for the cure of inoperable aortic and innominate aneurisms may be tried in the advanced cases involving the first and second divisions except coagulating injections, malaxation, electropuncture, and wiring (Moore method), which have proved worse than useless. Suffice it to say that non-operative methods of treatment, though occasionally successful, have failed to diminish seriously the mortality of the disease.

Operative Treatment.—No less than 18 different procedures have been adopted by the 130 or more operators. These may be divided in 6 fundamental groups: First, direct incision into the sac, with digital plugging of the orifices and ligation of the poles of the sac (Syme, 1860). Second, disarticulation at the shoulder-joint (Spencer, 1864). Third, ligature. Fourth, extirpation (King, 1890). Fifth, aneurismorrhaphy (Matas). Sixth, gradual obliteration of the artery on the proximal side with Halsted's aluminum band (1905).

The subclavian has been ligated for aneurism in 16 different ways, which are grouped by Jacobstahl as follows: (a) *Distal ligations:* (1) Axillary (Dupuytren, 1829); (2) carotid (Butcher, 1863); (3) axillary and carotid (Lloyd, 1888); (4) third division of subclavian (Poland, 1864). (b) *Proximal ligations:* (5) third division of subclavian (Colles, 1813); (6) second division of subclavian (Liston, 1820); (7) first division of subclavian (Arendt, 1826); (8) first division subclavian and carotid (Liston, 1838); (9) first division of subclavian, common carotid, and vertebral (Parker, 1863); (10) innominate artery (Valentine Mott, 1818); (11) innominate and carotid (V. Mott, 1863); (12) innominate, carotid, and subclavian (Willet, 1893); (13) innominate, carotid, and, subsequently, first portion of subclavian (Banks, 1885); (14) innominate, carotid, and vertebral (Bull, 1894); (15) innominate and carotid, later vertebral and internal mammary (A. Smyth, 1864). (c) *Proximal and distal ligations:* (16) First portion of subclavian and axillary (Clutton, 1896). The results obtained by these different procedures, except the more recent suggestions of Halsted (gradual obliteration by aluminum bands) and that of Matas (endo-aneurismorrhaphy), have been admirably summarized by Jacobstahl. He collected 21 new cases operated upon since 1890, which were not mentioned in previous communications. In his analysis he only considers operations performed for pathologic aneurisms. In order to appreciate the influence of asepsis

he divides them into two groups, *i. e.*, cases operated *before* 1890; and the other from 1890 to 1903.

Results of the operative treatment up to 1890: 75 cases: 55 deaths = 73 per cent. mortality. *Since* 1890, 25 cases: 4 deaths = 16 per cent. mortality. Favorable results, improvement, and relief: up to 1890, 75 cases: 17 improvements = 22.7 per cent. Since 1890, 24 cases: 17 improvements = 70.8 per cent.; reported cures, before 1890: 7 in 75 cases = 9.3 per cent.; since 1890, 12 in 24 cases = 50 per cent. Permanent cures, established by long observation, before 1890: 1 in 75 cases = 1.3 per cent. Since 1890, 5 (all extirpations) in 24 cases = 20.8 per cent.

Oberst, writing about the same time (1903–04), arrived practically at the same conclusions, viz., that the operative mortality of subclavian aneurisms had dropped during the aseptic period from nearly 80 to 22 per cent. Savariaud, at a later date, compiled the cases during the modern period from 1884–94, and concludes that the mortality has been reduced from nearly 80 per cent. to less than 18 per cent., and that in 22 cases of ligation or extirpation outside of the scalene muscles, there were only two deaths—9.2 per cent. mortality. In 6 extirpations of aneurisms of the third division there are no deaths.

In *regard to the life of the limb*, a notable improvement also is noticed, though it is a fact that even in the septic period gangrene of the upper extremity was comparatively rare after ligature of the subclavian for aneurism. In 39 proximal ligations of the subclavian for aneurism there were 3 fatal gangrenes of the arm and 4 of the hand. On the other hand, in Savariaud's 57 cases operated on since 1885 there were no gangrenes. According to von Bergmann (1877), 90 ligations of the subclavian artery on account of gunshot wounds escaped gangrene, except in a few fingers, yet the mortality was very high—70.6 per cent., chiefly on account of secondary hemorrhage and sepsis. Matas, reporting his experience with arteriovenous aneurisms of the subclavian vessels (Jour. Amer. Med. Assn., January 11, 1902), collected 18 cases from literature and summarized the liability of the limb to gangrene as follows: arteriovenous injuries, including ligation of both vessels, 13.5 per cent; after ligation of the subclavian artery alone, third division, 1.7 per cent., showing that in regard to gangrene the ligation of the subclavian in its third division, at least, is less dangerous than that of the axillary, which in the preantiseptic period was followed by 26.8 per cent. (Le Fort, 1867). Marichal reports 10 cases of extirpation of the sac, with 9 cures. The tenth case might be claimed a success, as the cause of death was not attributable to the method of treatment. No gangrenes are reported in this group. It is evident that in regard to the mortality, asepsis has worked a miracle in this at one time deadly field.

Savariaud, whose views and conclusions may be regarded as fully representing not only the French, but the modern continental attitude toward this group of aneurisms, concludes: (1) That for practical

purposes aneurisms of the subclavian artery must be divided into two groups: (1) extrascalenic; (2) mixed intrascalenic and extrascalenic aneurisms. The former are essentially surgical, calling for extirpation or ligation applied as close as possible to the aneurism. The two methods, proximal ligature next to the sac (Anel) and extirpation, are here of equal value. The ligature is to be tried first, followed by extirpation, if this is found to be at all practicable. In the second group the danger of the proximal ligation increases with the proximity of this to the heart. It is best to refrain from it as an initial measure, resorting to distal ligation on the Brasdor plan (see Innominate Aneurisms, Guinard's procedure), in which the immediate mortality is practically nil, and the end results are frequently remarkable. In the event of failure or relapse, other more radical or uncertain methods may be considered.

Thus far the methods of ligation and extirpation have been considered. There is evidence, however, to show that in all cases in which a bloodless field can be obtained by proximal control of the vessels the equally radical, but more benign and simple, procedure, of intrasaccular suture, is applicable with equal if not greater advantage. As the majority of the subclavian aneurisms are of the fusiform type, it is probable that only the obliterative method will be applicable in the majority of cases.

Thus far I have records of three cases of aneurisms of the subclavian tract operated upon by this method, followed in all by the cure of the aneurism and the complete preservation of the extremity.

The first is an atypical operation, reported by Parham (Trans. Southern Surg. and Gynecol. Assn., 1906). The subclavian was ligated just within the scaleni. Temporary arrest of pulsation occurred; but an incision into the sac was followed by a severe hemorrhage, which was controlled solely by the suture of the proximal opening within the sac, the distal end of the sac being ligated subsequently. The other two cases (Lozano and Munro) were typical endo-aneurismorrhaphies in subclavio-axillary aneurisms, in which the sac bulged above and below the clavicle. Provisional control of the circulation was obtained by a traction loop thrown around the subclavian at its exit from the scalenes. In both cases the recoveries were perfect and uneventful (Lozano and J. C. Munro, Boston, personal communication, December 2, 1907).

The advantage of the intrasaccular suture and obliteration of aneurisms over extirpation is the protection of important, if not vital parts and organs in immediate contact with the sac. The condition for a successful endo-aneurismorrhaphy is, however, a dry field, which can be obtained only by absolute control of the main trunk on the proximal side. In aneurisms of the third division, clamping the upper and lower poles of the sac, outside of the scalenes, will probably offer sufficient security, but in aneurisms of the first and second divisions, the innominate would have to be controlled on the right side, and in advanced and complicated aneurisms, in which

subjects, this alone would be a most serious problem. The future success of the radical operation by this or other methods will depend upon an early diagnosis, which at the present time should be made at a comparatively early stage, with the aid of radiography, even when the intrathoracic portion of the artery is involved.

In the mean time Halsted's suggestion (1905) to obliterate the main trunks by gradual occlusion with aluminum bands is well worthy of thorough trial in this particularly difficult and dangerous group of subclavian aneurisms (Jour. Exper. Med., March 1, 1909).

Axillary Aneurisms.—These constitute 3 per cent. of all arterial aneurisms. It is essentially a male disease—4 women in 69 cases (Koch). The age is from thirty to forty years; no spontaneous aneurisms of this region occur below twenty years of age (Koch).

Etiology.—Axillary aneurisms are frequently of traumatic origin. The artery is often wounded by bullets, stabs, falls, and violent efforts at the reduction of old shoulder dislocations. Often the traumatism is insignificant; *e. g.*, the pressure of crutches in old arterio-sclerotic subjects.

Pathologic Anatomy.—Axillary aneurisms usually originate in the parent trunk, but they may also develop in its branches, subscapular, circumflex, etc. It is interesting, as Delbet observes, to remember this, because if the classic ligation of the third division of the subclavian is applied in an axillary aneurism, the treatment will be more than useless, as the aneurisms originate in the collaterals, where they are aggravated by the ligation of the main trunk. Axillary aneurisms may encroach upon the subclavian, lifting up the clavicle, and filling the supraclavicular space. They are then properly classed as subclavio-axillary aneurisms, and should be treated as such. They often occupy the upper or lower part of the axillary space, but rarely begin in the middle division of this artery. In growing, they first displace and then compress the brachial plexus, causing intolerable pain in the arm and shoulder, the pain being associated and followed by paresis or even complete paralysis of the limb. Edema and cyanosis of the arm also result from compression of the vein, which blends with and finally becomes incorporated into the sac. Usually, these aneurisms grow quickly and attain large size. They erode the ribs and clavicle, and sometimes rupture into the pleura. The artery may be obliterated by the progress of the aneurism, and in this way an axillary aneurism may be cured spontaneously.

It is only in exceptional instances that aneurisms in this region have remained indolent and stationary. In one case the tumor remained tranquil for ten years, and in another, sixteen years. But they usually rupture early either into the connective tissue of the axilla, externally through the skin, or into the thorax.

The **symptomatology and diagnosis** of these aneurisms are usually clearly interpreted in the light of their anatomic relations. Pain and paresis or paralysis, which come on early, are dominant features throughout the entire course of the disease. At the present time,

when direct methods of intervention are the rule, the differentiation of aneurisms of the main trunk and of its branches has lost much of its importance. However, when the pulse remains unaffected, either in volume or rhythm, when an aneurism is known to exist in the corresponding axilla, the probability that that aneurism involves a branch and not the main trunk should be remembered.

The treatment of aneurisms of this region was at one time divided into: (1) Dietetic and medicinal; (2) direct and indirect compression; (3) proximal and distal ligation; (4) Antyllus, the old operation, and its modification by Syme; (5) extirpation; and (6) intrasaccular suture, which may be applied in any one of its three varieties. At present the relative safety of modern asepsis and improved hemostatic resources have made the operative treatment the first and not the last mode of attack. Furthermore, the comparative ease with which these aneurisms can be reached by open methods has discouraged—and very justly—a prolonged trial of the dietetic and medicinal treatment, except in a few and very exceptional cases, in which any operation is contraindicated. The ligature, which was usually applied on the proximal side, preferably on the third division of the subclavian, was associated with a fearful mortality in the preantiseptic period (45 per cent. to 34 per cent.). It is the same story all over—secondary hemorrhage, suppuration in the sac, gangrene, and septic complications, which here, as elsewhere, followed in the wake of the septic ligature. All this has disappeared since asepsis, though the risk of gangrene following acute traumatisms has not been altogether eliminated. This is particularly true when the vessels are injured in shoulder-joint dislocations. According to Stimson, Körte, G. Schmidt, Nemenoff, and Hessmann, the central ligature of the subclavian and axillary has been followed by peripheral gangrene in 16 per cent. of these cases. In 40 cases compiled by E. Wolff (1908), 25 per cent. of necroses occurred, and are to be expected when the axillary artery is ligated at the seat of injury or in its immediate vicinity. This great difference between the effects of ligation in acute traumatic injuries and in idiopathic aneurisms is attributable to the large extravasations which infiltrate and choke up the limb.

Though the ligature has become a benign procedure at the present time, the objections to its application in the treatment of axillary aneurisms are: (1) Frequent failure to cure; (2) liability to relapse; (3) frequent persistence of a hard tumor (organized clot) after apparent cure; (4) possible obstruction of peripheral branches by migratory emboli or propagated thrombus. Therefore, the method of extirpation is preferable, but, on the other hand, extirpation is also objectionable, because it inflicts dangerous trauma, injures important collaterals, and is likely to damage the branches of the brachial plexus and the axillary veins, which are so frequently amalgamated with the sac. Endo-aneurismorrhaphy after preliminary compression of the artery above and below the sac with padded clamps will permit

the obliteration of the main orifices and of the sac itself with a minimum of trauma. In a case reported by Ingels, of Jetmore, Kansas, November 1, 1906, he was able not only to obliterate a very large axillary aneurism, but to restore the main trunk as well. The aneurism was of pathologic origin in a man aged forty-three. He controlled the circulation with a loop ligature thrown provisionally around the third portion of the subclavian. He used iodin gut to reconstruct the artery over a guide, and obliterated the sac with superimposed sutures of chromic catgut without drainage. The patient recovered uneventfully and was perfectly well two months after the operation.

Aneurisms of the Iliac Group.—These may be divided into two distinct surgical groups: (1) Aneurisms of the outer (external) iliac tract; (2) aneurisms of the inner (internal) iliac or hypogastric artery and its branches.

I. The *common iliac, external iliac, the iliofemoral,* or inguinal (under Poupart's ligament), *and the common femoral* (to the origin of the profunda) constitute a continuous trunk, which, in a surgical sense, represents the prolongation of the abdominal aorta to the lower limbs. Aneurismal tumors, which develop in the external iliac tract, as above defined, have several characters in common which justify their classification as a separate group. These distinguishing features are: (1) They are all (with the exception of the femoral) aneurisms of the abdominal type, *i. e.*, partially, if not completely, invested by peritoneum, and most accessible by abdominal section and intraperitoneal manipulations, though the inguinal and upper femoral members of this group are also attainable by extraperitoneal routes. (2) They encounter little or no resistance to their growth and development on their peritoneal aspect; therefore, they grow rapidly, attain large proportions, and rupture more quickly than the aneurisms of the extremities, which are well supported by the surrounding resisting aponeuroses and other tissues. (3) Any treatment which attempts to cure these aneurisms, either by coagulating their contents, by obliterating the sac, or extirpating it, must necessarily influence the circulation of the lower limbs and may be followed by gangrene of the distal parts. (4) Absolute control of the circulation in the aneurisms of the iliac tract, including the common femoral, can only be obtained by compression of the abdominal aorta, a procedure which controls the collateral supply of both internal and external iliac groups. The procedure causes a complete ischemia of the iliac tract, and makes it "dry" for all surgical purposes, though even then there may be some bleeding in the sac of the inguinal and upper femoral aneurisms from the epigastric and circumflex iliac artery. (5) The iliac tract, as above defined, constitutes a natural surgical division of the aneurismal groups of the lower extremity. This tract, for surgical purposes, is bounded above by a line drawn across the abdominal aorta, on a level with the umbilicus, just above the bifurcation. On this upper umbilical line direct circular elastic compression may be applied with rubber tubing, as recently suggested

by Momburg (see Prophylactic Hemostasis, section on Hemorrhage). In this way the aorta is compressed against the vertebral column, at least in thin or relaxed individuals, under general anesthesia. Compression is best applied to the aorta, however, by opening the abdomen and temporarily clamping the vessel by protected rubber clamps, provisional tape ligature, fingers of an assistant, etc. Whether applied by extraperitoneal or intraperitoneal routes, the compression of the aorta becomes necessary, and is the only safe method of obtaining a reliable preliminary hemostasis of the iliac tract. The lower boundary of the iliac aneurismal tract is reached at the highest level of the thigh, where circular elastic constriction can be most effective in controlling the circulation of the lower limb. The aneurisms which develop above this line must be considered, for surgical purposes, as members of the *iliac group*, and those below it as of the *femoral group*. In this way a practical surgical division is established, which is based upon a method of circulatory control common to all aneurisms of the iliac group, regardless of anatomic landmarks.

II. The *aneurisms which develop on the internal iliac or hypogastric artery* are essentially of intra-abdominal or intraperitoneal type, except those that occur in its peripheral branches, as the gluteal, sciatic, obturator, pudic, etc. The common feature of these aneurisms is that the obliteration of the parent trunk of the internal iliac, or its branches, never compromises the nutrition or vitality of the lower extremity. It is only when the common iliac, or its continuation in the external iliac tract, becomes blocked or interrupted, that the internal iliac assumes the function of a supplementary collateral and nutrient of the lower extremity of the first magnitude.

Clinical Data on Iliac Aneurisms.—*Incidence.*—In our Charity Hospital (New Orleans) statistics there are 2 of the common iliac in 172 aneurisms recorded in ten years (Holcombe). In Crisp's classic group they appear 11 times in 551 aneurisms. In order of frequency the iliac tract is attacked by aneurism as follows: (1) Iliofemoral (at the groin); (2) common femoral; (3) external iliac; (4) the common iliac; and (5) the internal iliac. The vast majority occur in men (only 3 per cent. of the ilio-inguinal in women). They are frequent between the twentieth and fortieth years, and there is a tendency to involve the right side (85 right, 71 left; 4 bilateral aneurisms, Delbet).

Causes.—These aneurisms are either traumatic or pathologic (so-called spontaneous), or both. The pure traumatic aneurisms (stab, gunshot, blows, etc.) are relatively rare, and become less frequent as the aorta is approached, those who are wounded in these vessels usually succumbing to their injuries before aneurisms have time to develop. Indirect traumatism, including the rupturing effect of sudden violent effort, lifting, wrestling (increasing the intravascular tension), in rupturing the intima and media, are to be regarded as exciting causes only when a pathologic cause (arteritis, atheroma) exists as a predisposing condition.

The *prognosis* of iliac aneurisms of the main trunks is always serious; those of the outer iliac tract especially, both as regards the life of the patient and of the limb. Spontaneous recovery is possible, but is very exceptional. The prognosis is gravest in the pathologic aneurisms, chiefly because they are usually associated with extensive and inoperable lesions of the heart and arterial system. The danger to life is probably greatest in the common and external iliac groups; the danger from gangrene greatest (for anatomic reasons) in aneurisms of the common femoral, immediately below Poupart's ligament. The lack of peri-aneurismal support favors the rapid development and early rupture of the common and external iliac types.

When rupture takes place, death follows quickly, as there is no obstacle to the flow of blood into the peritoneal cavity. Sometimes the rupture takes place in the subserous connective tissue, forming immense hematomas which extend up to the iliac fossa into the lumbar region, or into the pelvic cavity, far beyond the original leak. Sometimes gangrene of the foot and leg occurs from compression of the main vessel and the collaterals by the hematoma. The aneurisms are rarely limited by the anatomic lines which define the extent of the arteries, hence the frequency of transition forms, such as aortic-iliac; iliohypogastric; iliofemoral or inguinal, etc. The iliofemoral or inguinal aneurisms more often begin in the common femoral, below Poupart's ligament. They extend usually only a short distance into the external iliac, the larger part of the sac extending under and below the crural arch. Aneurisms of the groin, which begin in the common or superficial femoral and extend upward to the external iliac, are still less frequent. The aneurism may be bisaccular, with an hour-glass constriction on a level with Poupart's ligament. These aneurisms may erode the pelvis (7 cases), the anterior lip of the acetabulum, and perforate into the hip-joint itself (Langenbeck, Matas). In shape, they may be sacciform or fusiform.

The surgical anatomy of the iliac tract is the key to the *symptomatology*. The early pains felt in external iliac aneurisms radiate from the iliac fossa to the thigh, along the track of the anterior crural branches. Varices, edema, cyanosis, and other evidences of saphenous engorgement result from femoral venous compression. The compression of the iliopsoas muscle will cause a psoas contracture, with an attitude of the limb similar to that observed in lumbar Pott's disease. As the tumor develops and approaches the surface, all the signs of aneurism become apparent. The diagnosis is a very simple matter when a pulsating tumor is felt in the groin or in the iliac fossa, and the distinct heaving expansile pulsation is associated with the characteristic bruits. Sometimes there is no pulsation, and, if it existed at one time, it may be forgotten by the patient; then the real and dangerous diagnostic difficulties begin. These aneurisms have been often confused with osteosarcomas, lymphosarcomas, and other tumors. What is worse, the sac becomes sometimes infected and inflamed, thus accounting for the very dangerous and

usually fatal error of opening these aneurisms under the impression that they are acute iliac phlegmons or cold abscesses. The classic and often quoted mistakes of Ferrand, Desault, Pelletan, Dupuytren, —all surgeons in chief of the Hôtel-Dieu of Paris,—prove clearly that even the most experienced may be deceived, and, what is worse, that even with a previous knowledge of this dangerous possibility, the error is still repeated. In a recent case, kindly reported to me by Dr. Anderson, of Chattanooga, Tenn., the accident happened when a large pulseless aneurism, supposed to be a large abscess in the iliac fossa, was freely opened by incision, a great gush of blood instantly revealing the true nature of the case. It was only the presence of mind and quick action of the operator that saved the patient's life. He immediately packed gauze into the cavity, and it was only after five square yards of gauze had been stuffed into the sac that the bleeding stopped. The packs were gradually removed in the course of two weeks and the patient completely recovered without further accident and after a very unique experience.

The diagnosis, as well as the treatment, of these aneurisms has benefited greatly by the recent advance of abdominal surgery, which permits a thorough intraperitoneal exploration of the tumor without opening it if the patient is placed in the Trendelenburg position.

Treatment of Aneurisms of the Outer or External Iliac Tract.— This must vary with the seat of the aneurism, its topographic relations, its size, and the general condition of the patient. Many patients cannot be operated upon at all, at least surgically, with any reasonable prospect of cure, especially if marasmic or suffering with advanced or multiple arterial, cardiac, nephritic, or pulmonary lesions. In these cases the medical methods of treatment recommended for aortic aneurisms are in order. A small aneurism of the external iliac, a little above the groin, in a thin subject, may be benefited and cured by digital compression, as shown by Shepherd, of Montreal. If the aneurism is very large and extends above Poupart's ligament for any great distance, it is evident that digital compression is out of the question. Possibly indirect compression of the abdominal aorta by Macewen's method or the instrumental aortic compressors (Lister's, Esmarch's, Signorini's) may be tried. Though the results obtained by indirect compression for iliac aneurisms is not encouraging, still the successful cases reported by Wheelhouse, Hilton, Mapother, and Holden, in the older literature, in which cure was obtained by compression of the aorta, are well worth remembering. According to Delbet, flexion has been tried five times without a single success. Richardson, of New Orleans, devised a special method of flexion of the thigh for external iliac and high femoral aneurisms, and obtained at least one symptomatic cure in 1879. Indirect compression of the abdominal aorta in iliac aneurisms should be attempted systematically only on patients who are able to stand prolonged anesthesia. If compression fails, after a fair trial, it should

be discontinued. Compression may at least help to develop the collateral circulation.

The treatment which has been most frequently applied to aneurisms of the external iliac tract is the ligature, either of the external or of the common iliac. The abdominal aorta has been ligated at least ten times for aneurisms of the common, external, and internal iliac arteries, but all these attempts failed. The common iliac was first ligated for aneurism of the external iliac by Valentine Mott, of New York, in 1827. Since that time the reported cases have been compiled by several writers—Stephen Smith, Barbosa, 1874; Kümmell, 1883; Tillmanns, and Dreist (Deutsch. Zeit. Chir., 1903–04, Bd. lxxi.).

In summing up the evidence from various sources we find: that the common iliac artery has been ligated 80 times, with 56 deaths, or a death-rate of 70 per cent.; 59 of these operations were done prior to 1880, during the preantiseptic period, with 46 deaths, or 77.97 per cent. mortality. In the 21 operations done since 1880, presumably with aseptic precautions, there were 10 deaths, which shows a reduction in the death-rate to 47.64 per cent.—a very decided improvement. Gangrene has occurred in the last 21 cases 7 times, or in 33.33 per cent.

In the preantiseptic period the extraperitoneal route was adopted, according to Dreist, in 48 cases, with 37 deaths,—77 per cent.,—and in the antiseptic period the same route was followed by a mortality of only 55.33 per cent. At the present time the extraperitoneal route has been practically abandoned, as the great superiority of the transperitoneal method is universally recognized. The mere opening of the peritoneal cavity for the ligation of the artery contributes very little, if at all, to the mortality of the operation; on the contrary, the transperitoneal route is less liable to septic complications than the long undermining and traumatizing dissections adopted by the older operators. The common iliac artery was ligated extraperitoneally as a prophylactic hemostatic in disarticulation of the hip by Schönborn (Würzburg), in 1883. Intraperitoneal digital compression to prevent hemorrhage in disarticulation of the hip was first applied by McBurney, of New York, in 1894. As a prophylactic hemostatic to control the circulation in an iliofemoral aneurism treated by endo-aneurismorrhaphy, the common iliac was clamped provisionally, at Matas' suggestion, by Danna, of New Orleans, July 19, 1907. Since that time temporary compression of the common iliac alone, or combined with compression of the aorta for the same purpose, has been applied by Matas (1907), Levi Old (1907), Balch (1907), and Gessner (1909), in 5 cases of iliofemoral aneurism, and always without accident or complications from the peritoneal side.

Extirpation.—This procedure has been applied in comparatively few instances—thus far only in aneurisms of the external iliac artery. Under this heading are classed the cases reported by Bobbio (1881), Quénu (1895), Basy, Dollinger (1897), Schorpf (1898), and Brewer (1901). Recovery followed in all but Schorpf's case, in which a high

thigh amputation became necessary on account of gangrene (20 per cent. of gangrene in this group).

Intrasaccular Suture Method (Endo-aneurismorrhaphy).—Though most recently introduced, this has a record of 7 operations on aneurisms of the iliac group: 5 iliofemoral and 2 external iliacs. Of the iliofemoral group, 2 operations were atypical, because in addition to the obliteration of the sac by suture, the external iliac was ligated immediately above the aneurism (Vaughan and Girdano). All these cases recovered from the operation without gangrene, except one, in which secondary hemorrhage occurred in the sac from premature yielding of the sutures, which compelled secondary ligation of the external iliac. It was then that gangrene occurred and death followed from exhaustion. In all these cases the obliterative operation was adopted, except in Danna's case, where a reconstructive operation was performed. In this case the aneurism relapsed in two months after recovery from the first operation, ultimately rupturing, with fatal results. In all probability this event could have been avoided if the patient had listened to advice and returned to the hospital to have the second (obliterative) operation performed. Two cases of external iliac aneurisms, operated by endo-aneurismorrhaphy, one successful, by Balch and Murphy, of Boston (Bost. Med. and Surg. Jour., vol. clix., No. 26, December 24, 1908); the other reported by Levi Old, Norfolk, Va., died from pulmonary embolism (proved by post-mortem) within twelve hours after the operation, nothing abnormal or unusual having been found at the site of the aneurismal operation. In Balch's very unique and brilliant case a large traumatic aneurism which filled the iliac fossa was cured by a restorative aneurismorrhaphy. The common iliac was controlled with a Crile clamp, and, after opening the sac and clearing out the clot, the single orifice of communication was closed by sutures, leaving the lumen of the wounded external iliac open and pervious. The aneurism was cured, and the patient recovered completely without any disturbance in the circulation of the leg.

In this category I will also place the cases of diffuse traumatic aneurism reported by Pringle (1901), de la Torre (Zent. Chir., No. 48, 1908). We have already referred to the remarkable case (unpublished) of Anderson, of Chattanooga (1909) (p. 336). It is interesting to notice that in the hands of the Japanese surgeons, Kikuzi, for instance, the method of intrasaccular ligature, applied by him after free incision and evacuation of the sac, in the traumatic aneurisms which occurred among the Japanese and Russian soldiers, was followed by remarkably satisfactory results. In 5 arteriovenous and one arterial aneurism of the external iliac and four of the common femoral in which the injured vessels were ligated in situ no fatalities or gangrenes occurred. (See method of intra-saccular ligature in the "Treatment of Aneurism," and also under Arteriovenous Aneurisms.)

Aneurisms of the common femoral, which include the origin of its superficial and deep branches (profunda femoris), are to be considered

surgically in the same light as iliofemoral or inguinal aneurisms. The traditional and well-founded fear of secondary hemorrhage, with all its disastrous consequences, following the ligation of the common femoral below the origin of the epigastric and circumflex iliac branches (58 per cent. secondary hemorrhage, 51 per cent. deaths; Barwell, Ashhurst's Surg. Encyclop., vol. iii., 1883), led the older surgeons to condemn ligation of the common femoral and to ligate the external iliac, which was less liable to secondary hemorrhage (22 per cent. mortality; 27 per cent. secondary hemorrhage; 8 per cent. gangrenes, Rabe-Barwell statistics, Ashhurst's Encyclop. Surg., vol. iii.). The difference in the results of the ligation of the two arteries was due to the fact that the collateral circulation in the common femoral is so great that it interfered with the organization of the thrombus, so that when the ligatures cut through the artery by suppuration and ulceration, secondary hemorrhage occurred. On the other hand, the external iliac is comparatively free from branches, so that a thrombus could organize undisturbed after a ligature, at least sufficiently to plug the artery after the ligature had cut through.

Since the advent of the absorbable aseptic ligature, the danger of secondary hemorrhage has been practically eliminated; but that of gangrene, though much diminished (18.75 per cent. after external iliac ligations for femoral aneurism, Delbet, 1895), still remains. The danger from the ligature in the treatment of aneurism, especially in so vascular a region as the upper femoral tract, is that the stagnation which occurs in the sac is only partial. There are often currents which persist through the collaterals sufficiently long after the ligation to detach loose fragments of clot which block the peripheral arteries. Sometimes a thrombus may extend all the way from the sac into the profunda or superficial femoral, and block these vessels for several inches. Hence the present tendency to attack aneurisms by direct intervention, either by extirpation or by open section, clearing out all the clot and obliterating the orifices by suture. It is to Delbet's lasting credit to have demonstrated that there is infinitely less risk to the limb by obliterating an aneurismal artery at the diseased part than by creating two obstructions in the same artery—one at the point of ligature and the other in the coagulated sac. However, to extirpate these aneurisms in areas which fairly bistle with spurting branches is no simple matter unless an absolutely dry field is obtained; even then the danger of wounding the vein, which would at once greatly add to the danger of the limb, is not to be disregarded. To avoid this risk and diminish unnecessary traumatism, especially to the numerous collaterals which exist in this region, the intrasaccular suture method (endo-aneurismorrhaphy) can be resorted to with advantage. I have a record of six cases in which high femoral aneurisms seated above the line of practicable circular elastic constriction were treated by this method. In two of these, Frasier (Annals of Surgery, vol. xlvi., 1907) and Mitchell (Washington, 1907) encountered severe hemorrhage in spite of the control of the proximal

(iliac) end of the sac, the intermediary collaterals opening freely into the sac. In two others, one by White, of Savannah, Ga., 1905, a remarkably brilliant case, of restorative endo-aneurismorrhaphy for traumatic aneurism of the femoral, and the other, by Stafford, of New Orleans (see Matas, Jour. Amer. Med. Assoc., September 29, 1906), there was also free bleeding after opening the sac in spite of provisional ligatures applied to the common femoral in the first case, and to the external iliac in the last. The bleeding came chiefly from the profunda, which was incorporated in the sac, as is usual in these cases. Whelan obtained a notable success in an unusual aneurism of this type, the bleeding being controlled by a simple provisional traction (tape ligature) on the external iliac. Crile (1908) also obtained a brilliant cure. He controlled the bleeding by compressing the upper and lower poles of the aneurism with the Crile clamp, and was able to suture and obliterate the sac without interrupting the lumen of the artery. In all these—6 cases—a recovery followed with the cure of the aneurism, except in 2 cases. In one (Stafford) gangrene followed the ligation of the external iliac high up, on account of the rupture of an aneurism which had formed at the point of traction, where the provisional ligature had been placed while operating on the common femoral; in the other (Frazier) the patient recovered and the aneurism was cured, but gangrene occurred on account of the formation of a thrombus in the popliteal. The artery remained patulous from the point of aneurismal obliteration in the thigh to the popliteal space. The uncertainty of obtaining a bloodless field in high femoral aneurisms, even when the proximal and distal poles are controlled by provisional ligatures, has led me to practise and recommend the compression of the aorta or common iliac as a preliminary procedure in such cases. It is evident that while the statistics of the intrasaccular method of suture are not yet large enough to justify dogmatic conclusions, there is no doubt that in this difficult region it is already in a position to stand comparison with extirpation or other methods of radical cure.

Aneurisms of the Internal Iliac Tract—"Aneurisms of the Buttock." —Aneurisms of the hypogastric arteries are also described as "pelvic aneurisms." While all the branches of the internal iliac may become aneurismal, including in this the uterine artery, aneurisms of which have been reported in a few instances, the aneurisms of the internal iliac, which are most frequent and of the greatest interest to the surgeon, are those which appear in the buttocks as dilatations or extravasations of the gluteal or sciatic arteries. These may appear in the intrapelvic portion or origin of these vessels, or in their extrapelvic distribution. The aneurisms limited strictly to the intrapelvic portion are so rare that they need not be considered. On the other hand, the extrapelvic often extend into the pelvis, and some are, therefore, intrapelvic and extrapelvic, the groove between the sacs corresponding to the sacrosciatic notch.

The majority of the gluteal and sciatic aneurisms are caused by

traumatism, either directly or indirectly, *i. e.*, they are pulsating hematomas, which have become encysted and well defined. Circumscribed traumatic aneurisms are the rule; the majority occur in males. In 38 cases, 12 were due to wounds (stabs) and 12 to ruptures and lacerations caused by fracture of the pelvis or contusions, falls on the seat, etc. The gluteal artery is more frequently injured by direct wounds (stabs); the sciatic by falls on the ischium or seat, which fracture the pelvis or tear the artery at its exit from the sacrosciatic foramen. The left side is more frequently affected than the right. Rupp, in his recent thesis (Inaug. Dissert., Königsberg, 1907), reporting a successful case of extirpation of gluteal aneurism by Lexer, has collected 45 cases of gluteal aneurisms, of which 22 were of traumatic origin and 23 spontaneous (8 indirectly associated with trauma).

Size.—This varies from that of an egg to that of a large irregular tumor which may fill the hollow of the sacrum and the space between the ischium and the great trochanter.

Symptomatology.—This is based chiefly upon a knowledge of the anatomic relations of the gluteal and sciatic arteries. The appearance of a tumor shortly after traumatism is always suggestive of aneurism. The nature of the tumor is confirmed when expansile pulsation is felt. The spontaneous tumors are small and slow in developing. The traumatic are usually large, widely diffused, and of rapid development. Sciatic aneurisms are distinguished from the gluteal—first, by their greater proximity to the tuberosity of the ischium; second, by their lateral mobility. The proximity of the sciatic nerve explains the preliminary pains which are so often mistaken for sciatica before a palpable tumor can be felt. If allowed to go unchecked, they terminate fatally. They all tend either to rupture subcutaneously, and sometimes choke up the thigh with a massive circumferential extravasation; or externally, causing almost immediate death. It is easy to mistake these aneurisms when they are filled with hard clot for sarcomata or even abscesses. Exploration with a large aspirating needle will often clear up an obscure diagnosis.

Treatment.—Past methods of treatment—coagulating injections of perchlorid of iron, galvanopuncture, etc., have all given way to surgical treatment by the open method, *i. e.*, incising the sac with or without preliminary ligation of the internal iliac. The common iliac was ligated four times, with three deaths, in the preantiseptic period. The ligation of the internal iliac artery on the Hunterian plan has been justly regarded, until the modern period, as a very dangerous operation. D'Antona, of Naples (Archiv. Internat. Chir., vol. ii, 1903–04), in reporting a cure of bilateral sciatic aneurisms (spontaneous) in the same subject, by the successive ligation of both internal iliac arteries, published all the reported cases of ligation of this artery for aneurism from 1869 to 1903; in all, 25 cases, with 15 recoveries and 10 deaths, or 40 per cent. mortality.

It is evident that these statistics must all be revised in the light of modern technic, and to mix up the old with the new cases is simply

a profitless undertaking. At present the ligation of the internal iliac by the intraperitoneal route with the aid of the Trendelenburg position is in itself a comparatively simple and benign procedure. In view of the uncertainty of the effects of the ligation of the internal iliac and the liability to relapse (see Gillette's case, Annals of Surgery, vol. xlviii., 1909) the combination of the ligature of the internal iliac, whether permanent or provisional, with the free incision of the sac and its obliteration by suture (obliterative endo-aneurismorrhaphy), should be adopted in all the cases in which the patient can be anesthetized and stand the effects of a laparotomy. When we consider that the old operation, the modified Antyllian, as performed by Syme, as the "method of intrasaccular *ligature,*" cured 12 of the 14 cases reported by Delbet, a mortality of 16.66 per cent., as against the 40 per cent. mortality following the Hunterian ligation of the internal iliac, it is evident that these comparatively good results can be still further improved with a modern technic. The clear demonstration of the simplicity and thoroughness of the method of intra-saccular suture (endo-aneurismorrhaphy) has been recently shown most effectively in a gluteal case reported by Robert Abbe, of New York (Annals of Surgery, vol. xlviii., 1908), wherein the technic is clearly illustrated and described.

To conclude: In *fully formed* aneurisms with well-defined sac-walls incision of the sac and suture of the orifices, with final obliteration by the intrasaccular method of suture, is to be preferred as the method of election, provided prophylactic hemostasis can be obtained by preliminary intraperitoneal ligation or temporary compression of the internal iliac. *In acute traumatic* diffuse aneurisms without sac walls the same prophylactic hemostatic procedure should be adopted, but instead of suturing the walls of the cavity, the wounded artery should be sought and ligated or sutured wherever it may be accessible in the aneurismal cavity. In gluteal or sciatic aneurisms which begin in the pelvis (rare, and usually pathologic) the ligation of the internal iliac trunk, as near the aneurism as possible, may be sufficient. The smaller pathologic aneurisms of the same vessels, which are well defined and circumscribed, outside of the sacrosciatic notch, may be treated most satisfactorily by a preliminary incision exposing the upper and lower poles of the aneurism, followed by the extirpation of the sac.

Aneurisms of the Femoral Regions.—(From the bifurcation of the common femoral to the origin of the popliteal.) For the reasons already given, only such aneurisms will be considered as members of this group which begin in the thigh below the highest level, where circular elastic constriction is practicable for hemostatic purposes. In this region, on account of their frequency, the most important aneurisms are those of the *superficial femoral.* Aneurisms of the profunda are probably ten times less frequent than those of the superficial femoral, and those of the superficial femoral are estimated to be four times less frequent than those of the popliteal (85

femoral; 358 popliteal, Delbet). It is readily appreciated that when either one of these two trunks alone is obliterated at the site of an aneurism, the integrity of the circulation below the obstruction is not imperiled, provided the other is patulous. The majority of these aneurisms are of traumatic origin, though the spontaneous variety, due to pathologic lesions of the artery, are not rare. In fact, *multiple* aneurisms are more frequent in the superficial femoral tract than in any other *peripheral* vascular area. They sometimes appear in succession in the femoral artery in connection with others of the iliac tract. The cases collected by Souchon (N. Y. Med. Jour., November 2, 1895, p. 545), in which as many as four aneurisms existed in succession and in the same individual and in the same artery (ilio-femoral tract), are examples of this pathologic peculiarity of the large arteries of the lower extremity. The aneurisms develop at the apex of Scarpa's triangle; are usually globular or spherical in shape; those below are of flatter form, as they are compressed against the bone and against deep muscular planes. Compared with popliteal aneurisms, femoral aneurisms grow with less rapidity, and there is less pain and disturbance from compression of the perianeurismal nerves and veins. Therefore there is less pain and less edema in superficial femoral than in popliteal aneurisms. Sometimes aneurisms develop in the branches of the femoral (circumflex, muscular, anastomotica, etc.), the superficial femoral artery itself being readily distinguished and separated from the aneurism, especially in thin subjects.

Treatment.—Digital compression of the common femoral at Poupart's ligament may be tried with some expectation of success. The most serious objection to this method, as applied to this group of aneurisms, is in its comparative inefficiency. In his earlier series Delbet reports 20 cases with 11 recoveries. In the failures there were 2 gangrenes. In the later series of 1895 the same author quotes 11 cases treated by ligature; 10 alone are considered available for study; of these 10, only 6 were cured; of the 4 failures, 2 suffered gangrene of the leg—in all, 30 cases with 13 failures, among which were 4 gangrenes. In one case another aneurism developed at the seat of the ligature. In the preantiseptic period Rabe (1875), in his collection of 952 ligations of the main arterial trunk, established the following percentage of gangrenes that followed the ligature for aneurisms of the lower extremity. The common femoral, 36 per cent.; superficial femoral, 22 per cent.; the external iliac, 19 per cent. Scriba, ten years later, in his analysis of 103 ligations on the Anel or Hunterian plan for aneurisms, states the proportion of peripheral gangrenes as follows: After the ligation of the external iliac, 9.1 per cent.; after the ligation of the femoral tract, including the common femoral, 5.3 per cent.

Extirpation.—Delbet records 9 cases of extirpation and 9 of the old Antyllian operation (double ligature, incision, and packing); in all, 18 cases of direct intervention without a single death or gan-

grene. He has shown in this group, as well as in all others involving the peripheral arteries, that *direct intervention* is always safer, from gangrene of the limb, than the ligature, and especially the Hunterian ligature.

Intrasaccular Suture (Endo-aneurismorrhaphy).—I have collected reports of 21 femoral aneurisms operated on by this method. Of these, 6 were high femoral aneurisms, including the common femoral and its divisions, and have been referred to elsewhere. Fifteen (15) involve the superficial femoral in its middle or lower thirds. Six of these operations were of the *restorative* type, in which the aneurismal sac was obliterated without occluding the lumen of the parent artery, and in another a *reconstructive* operation (Craig Barrow's case) was performed, in which a new channel was built out of the sac-walls; in all, 7 cases in which it was possible to cure the aneurism without obliterating the artery. In the remaining 8 the obliterative suture was performed. In the entire group of 15 cases a cure was effected without a death and without a single gangrene. The simplicity and safety of the intrasaccular suture, as compared with other radical methods, and especially with extirpation, are perhaps more apparent in this region than in any other.

Popliteal Aneurisms.—Aneurisms of the popliteal artery are by far the most frequent of the surgical and operable types of this disease. In a collection of 106 aneurisms covering all the important regions of the body, which have been operated upon by the intrasaccular suture method and collected by myself since 1903, we find that 62, or 58 per cent., involve the popliteal region. In the same collection, of 95 aneurisms of the lower extremity, including the iliac vessels, 66.4 per cent. are popliteal aneurisms. According to Delbet, popliteal aneurisms constitute over one-third of all the peripheral and surgical aneurisms. Owing to their frequency, popliteal aneurisms always suggest themselves to the surgeon as the standard of comparison or basis of study when any new question is raised in connection with the treatment of this disease.

Etiology and Pathogenesis.—Popliteal aneurisms are rarely of purely traumatic origin, certainly they are not often caused by gross violence or recognizable wounds. In the majority of the cases the patients cannot give any history of direct objective violence, but on careful questioning there is always a history of strain or muscular effort which suddenly and repeatedly increased the arterial tension. Of the various theories suggested to explain the greater frequency of these aneurisms, that of Delbet is probably the most plausible. According to him, the internal and middle tunics are ruptured in violent lifting efforts, in which the arterial tension is suddenly exaggerated, while the leg is acutely flexed at the knee. The rupture of the coats may be very slight, leading to no appreciable symptoms at the time of the occurrence; or it may be so complete as to cause prompt thrombosis in the vessel, this being followed by a series of signs and symptoms which are unmistakably indicative of arterial

obstruction. Though Adelmann's experiments would seemingly contradict the importance of acute flexion at the knee as a causative factor, it is evident that such flexion is a decided impediment to the blood-stream at the popliteal. It is well known that, for this reason, flexion alone may be utilized as a means of curing the disease. Delbet's theory is in accord with the fact that the majority of these cases occur in laboring men, very rarely in women, and that a history of syphilis, alcohol, and other causes of arterial degeneration is frequently present. The frequency of bilateral simultaneous or coincident aneurisms in both popliteal spaces and other regions in the same subject also confirms his view.

Pathologic Anatomy.—Spontaneous aneurisms of the popliteal very rarely involve more than a comparatively small segment of this artery. *Fusiform* aneurisms, as defined in the text (see Morphology of the Sac, etc.), involve a larger section of the artery than the *sacciform* aneurisms. Sometimes an aneurism that will fill the entire popliteal space, compressing and displacing its contents, will involve a section of the artery not more than half an inch in length.

Popliteal aneurisms may be classified, according to the part of the vessel involved, into: (1) Upper or femoropopliteal; (2) middle; (3) lower or popliteocrural aneurisms. Probably Gancel's original division into upper and lower popliteal aneurisms (see Paris Thesis, 1879) is sufficient for all surgical purposes. The gravity of these aneurisms and the danger of gangrene which may follow their obliteration increase as they descend from the upper end of the space to the bifurcation of the popliteal. The upper or femoropopliteal aneurisms find more space for expansion and are less likely to compress the veins and artery; and, what is more important, they involve a relatively small number of collaterals. Those of the lower popliteocrural group, especially if they attack the terminal division of the artery, are compelled to develop in a narrow compressed space, giving rise very promptly to venous obstruction and nervous pressure-disturbances from the popliteal and peroneal nerves, which fuse into and finally blend with the sac. The danger of gangrene of the foot and other parts is greatly increased in this variety, because of the ease with which the bifurcation of the artery into its anterior and posterior tibial branches is blocked by a thrombus, and because the important collaterals (superior and inferior articular, azygos, and the muscular branches) all spring from the sac or open into it, so that if the sac is filled with coagula and the collateral orifices are occluded, it is evident that the only avenue for the collateral circulation of the leg is through the anterior tibial recurrent, the muscular, and a recurrent branch from the peroneal.

The upper popliteal aneurisms, when opened, show a comparatively small number of collaterals opening into them; those of the inferior tract, especially those in that part of the artery which extends from the level of the interarticular line to the lower border of the popliteus, become, as Delbet puts it, "a veritable rendezvous

of arteries." In lower popliteal aneurisms it is, therefore, most important that the least number of collaterals be sacrificed. In fact, the lower pole of the sac and its outlet should be closely watched when the sac is opened, to prevent thrombosis of the terminal artery at its bifurcation. The lower pole of the sac should always be cleared by gentle swabbing with a moist sponge dipped in saline solution, and if a tendency to obstruction by clotting is observed, the orifice leading to the lower pole should be lubricated with aseptic vaselin, to prevent it. The sac may fill up the entire popliteal space, but it is very unusual for it to send prolongations or diverticula under the aponeurotic bridge of the soleus, which defines the boundary line between this vessel and the branches to the leg. Diverticula often form upward, on the inner side of the condyles, and downward, between the gastrocnemii. The popliteal veins and the external saphenous and the popliteal nerve soon become adherent to the sac, which fuses with all its surroundings by a gradual diffuse sclerogenic cellulitis, causing neuralgia and traumatic neuritis from compression of the nerves, and often followed by trophic and vasomotor disturbances. As the tumor grows, it meets with the greatest resistance in the lateral ligaments, condyles, intercondyloid space, posterior surface of the tibia, and the popliteal aponeurosis posteriorly. It is the resistance of these tissue planes which gives form to the sac and flattens the spheroid on a level with the deeper joint surfaces. It is also the cause of the phenomenon, which we have elsewhere described as the *rotation of the sac*, by which the poles of the aneurism are gradually displaced either on its meridional or equatorial planes. (See Pathology of Aneurism and Morphology of Sac, p. 221.)

When these aneurisms reach their terminal stages without interference, they stretch and absorb the ligaments and erode the bones until they finally rupture into the joint or externally. Instead of rupturing into the joint (hemarthrosis), the sac ruptures into the connective tissue, forming diverticula, or externally, where the popliteal aponeurosis has yielded and allowed the skin to undergo atrophy and ulceration. The lymph-glands of the popliteal space are usually enlarged; thus, in cases of pulseless aneurism, favoring the error of mistaking them for malignant tumors.

On opening the sac we find usually two fundamental varieties of aneurisms, previously referred to under the head of sacciform and fusiform aneurisms. (See Morphology and Classification of the Sac.) Between the two types we find innumerable gradations, so it may be difficult, at times, to say positively whether it is of the sacciform or of the fusiform type. In the majority of the cases the sac enlarges backward, *i. e.*, between the artery and the popliteal aponeurosis; in others, laterally, especially to the inner side of the knee. In a much smaller number the artery dilates posteriorly and the sac forms between the posterior ligament of the joint and the vessel, thus lifting the main trunk from its bed and raising it on the convexity

of the aneurismal spheroid to the surface. If the operator is not mindful of this possibility, he may wound the artery with the first stroke of the knife on opening the sac. This can be avoided only by the careful and deliberate dissection of all the tissues down to the sac. The relative frequency of the types of aneurisms found in the popliteal space may be roughly estimated by the relative frequency of the various types of endo-aneurismorrhaphy performed in 50 carefully studied aneurisms of this region, treated by this method. (See Treatment.) The sac itself may be perfectly formed, but many times it is only complete at its attachment to the artery, becoming thin, irregular, and unrecognizable in the peripheral and more distant parts. Sometimes the sac is absolutely adherent to the ligaments and the bones, so that if any attempt is made to peel it off, the joint may be widely opened. Under these circumstances the rigid, unyielding, adherent walls, and especially the floor of the sac, cannot be obliterated by infolding or approximating its walls by suture, as is done in the typical intrasaccular operation. The main orifices of the collaterals can, however, always be sutured, after which the obliteration of the cavity may be accomplished by lining wth skin-flaps or by methods suggested under "Treatment of the Sac," p. 276.

Symptomatology.—The earlier effects of aneurismal dilatation of the popliteal artery are interpreted by the patient usually as a simple hindrance to moving the knee, complete extension or flexion becoming especially difficult and painful. When the pressure signs begin, a slight edema of the foot or leg, some numbness of the foot, then sharp painful radiations to the leg, are complained of. Usually the diagnosis is easy when the tumor is sufficiently formed to be felt near the surface by pulsation, murmur, and all the characteristic signs of aneurism.

Prognosis.—The usual evolution of popliteal aneurism is rapid; the progress of the tumor is sometimes temporarily arrested when the sac fills the space, but it soon breaks through the resistance of the aponeurosis. Spontaneous cure is exceedingly rare. Sometimes an apparent or symptomatic cure is obtained by the coagulation of the contents, leaving a simple channel which connects the inlet and outlet of the passage. In other cases the foot or the leg becomes gangrenous, just as the sac is obliterated by clot. Spontaneous gangrene occurs more often in the course of the popliteal variety than after any other aneurism. There are two types of this spontaneous gangrene: First, that which attacks only the foot, when the gangrene is moist, and is due to the blocking of the veins, as well as the arteries. Second, more often the gangrene is dry, and is limited to the foot. Sometimes the gangrene spreads from the foot to the knee, the vein being often thrombosed from stasis and obstruction in the neighborhood of the sac.

Treatment.—During many years, even down to comparatively recent times, amputation was the only treatment applied for the relief of popliteal aneurism. Hemorrhage and gangrene were feared in every

case. In 1742 Guénault and Vandemesse proposed the ligation of the artery above the sac, but no attention was paid to this suggestion. In 1744 Keyslere audaciously incised a sac, thus reviving the old Antyllian operation, which hitherto had been applied only to aneurisms of the elbow. He cured 3 patients. A fourth, however, succumbed. "Infection, suppuration, aseptic complications were inevitable at that time, and the great mortality attending any direct intervention on the sac led to the prompt abandonment of Keyslere's procedure and a return to amputation. In 1785, and only six months apart, Desault and Hunter both practised and advocated the ligature, which then became an acknowledged method of treatment."

In the discussion of the general treatment of aneurism we have fully considered the different methods of treating peripheral aneurism, taking the popliteal variety as a type and standard or basis of comparison. We have presented the general statistical data, which are necessary to institute a comparison between the bloodless and the bloody or open methods of treatment. According to Scriba (1885), the ligature of the femoral for popliteal aneurism led to 5.3 per cent. of gangrenes, and of the popliteal itself, for the same cause, to 28 per cent. of gangrenes. At the meeting of the German Surgical Society of 1892, following the report of a case of bilateral popliteal aneurism treated by extirpation, communicated by M. Schmidt, who had also collected 10 similar cases, 9 additional cases of extirpation were brought to light; in all, 21 cases of popliteal aneurism treated by extirpation, followed in 2 cases by gangrene requiring amputation of the leg, *i. e.*, 9.5 per cent. gangrene (E. Wolff, Beit. klin. Chir., Bd. l, H. 3, 1908), von Frisch, reporting the cases in von Eiselsberg's clinic (Archiv. klin. Chir., Bd. lxxix., 1906), describes 9 aneurisms of the popliteal artery,—5 arterial and 5 arteriovenous, of which 7 were treated by extirpation, with consecutive gangrene of the limb in 2 instances—that is, 22 per cent. gangrenes following this method. In the Boer war Stephenson reports that the femoral artery was ligated 40 times for traumatic aneurisms of the femoral and popliteal vessels, with 7 gangrenes. According to E. Wolff (loc. cit.), in his very comprehensive study of the effects of ligatures on the main vascular trunks, gangrene of the lower limb occurs in 50 per cent. of common iliac ligations, in 25 per cent. of common femoral ligations, in 14.9 of popliteal ligations, in 12.7 of superficial femoral ligations, in 11.2 per cent. of external iliac ligations. Werner, quoted by Nasse (Deutsch. Chirurg., Lief. 66, 1, 1897), finds that since 1875, 35 cases of popliteal aneurism treated by excision or extirpation were followed by a mortality of 8.75 per cent., and gangrenes in 5.71 per cent.

Quoting from Delbet's classic compilation of statistics, we may recapitulate the evidence in regard to the methods of surgical treatment recommended and practised up to the present time as follows: The different methods of compression, as applied to popliteal aneurism, yielded, up to 1888 (preantiseptic period), the following results: 223 popliteal cases: 51.64 per cent. cured, and 48.36 per cent. failures, including 13 deaths from gangrene and infection. Of the above

223 cases, 73 were treated by *Reid's method* (elastic bandage), with 49.33 per cent. recoveries and 50.67 per cent. failures, including 5 deaths (4 from gangrene of the limb). *Digital compression* in 59 cases yielded 49.15 per cent. cured; 50.83 per cent. failures. *Flexion*, 49 cases: 36 per cent. cured, 64 per cent. failures, including 1 death and 2 amputations for gangrene.

Operative treatment of popliteal aneurisms from 1884 to 1894 (aseptic period).

Ligation (Hunterian), 42 cases: 87.5 per cent. recoveries; 12.95 per cent. failures. Of the recoveries, 8 were imperfectly cured; 10.5 per cent. of these had gangrene of the toes (5.48 per cent.); 3 out of the 5 failures had gangrene requiring amputation of the leg.

Relapses after Ligature in Popliteal Cases.—According to Delbet, 4.5 per cent. of the cases ligated relapsed, and other methods had to be resorted to. In 15 per cent. of the reported cases the operation failed to give complete relief because of the persistence of the tumor, though not pulsating.

Radical operation (same period), 32 cases: extirpation (Purmann's operation), 19; incision and packing (Antyllus), 13. Results: cure of aneurism in all; no deaths.

Local Results. In 10.4 per cent. of the cases of extirpation superficial gangrene of the foot in patches, not requiring amputation, occurred. In 8.33 per cent. of the cases operated on by the Antyllus method gangrene followed, requiring amputation.

Against these statistics we would oppose the result of our first series of 50 cases of endo-aneurismorrhaphy collected by myself, since my first report to the American Surgical Association in 1902 (published in the Transactions for 1902 and in the Annals of Surgery, February, 1903) to June, 1908 (see Jour. Amer. Med. Assoc., November 14, 1908, vol. li.). In the 50 cases, 10 were treated by the reconstruction of the artery out of the sac-wall (reconstructive endo-aneurismorrhaphy). In 8, the single foramen of communication, leading from the main trunk to the interior of the sac, was closed by suture, and the sac obliterated in the same way without encroaching upon the lumen of the vessel (restorative endo-aneurismorrhaphy). In 32 the sac was obliterated after the suture of all visible orifices, including the section of the artery involved in the aneurism. These 50 cases represent a series of aneurisms in which those of pathologic or so-called spontaneous origin largely preponderated. Furthermore, the aneurisms involved the popliteal artery in all parts of its course, but with a preponderance of the middle and lower (popliteocrural) variety. The *results* are: one death from tetanus, which was not attributable to the method; two gangrenes (one recovered and the other died of tetanus). In both cases the gangrene possibly might have been avoided, as the vein in the two instances was accidentally injured and ligated (which was not the fault of the method). Secondary hemorrhage occurred in one reconstructive operation six weeks after the operation and four weeks after the ligation of the superficial femoral. Relapses: three (only after the reconstructive

operation), but in one of these a complete cure was obtained three weeks after, by reopening the sac and obliterating it after suturing the orifices that led to the main artery.

Since this report was submitted to the American Medical Association in June, 1908, 12 additional popliteal aneurisms operated on by the intrasaccular method have been reported to me—all without a death, gangrene, or relapse. To sum up, then, in 62 popliteal aneurisms treated by Matas' method there was one death, avoidable, and two gangrenes (3.1 per cent.), also avoidable, and three relapses, one of which was cured by a secondary intrasaccular operation. We should also bear in mind that in 18 of the 62 cases, nearly 30 per cent., it was possible to obliterate the sac without interrupting the continuity of the blood-stream.

The simplicity of the intrasaccular method, as compared with extirpation, and the security it gives to the limb when, as in this region, the essential features of the intra-aneurismal technic can be carried out easily, make this the method of election in all cases in which a direct or radical intervention is indicated.

In the section on General Treatment I have sufficiently considered the more recent suggestions which have been offered and practised in a few exceptional cases of popliteal aneurism. Thus the methods of extirpation of the sac with a lateral or circular suture of the artery—the so-called "ideal operation" (Murphy, Garrè, Lexer, Martin, Enderlen); the operation in which the aneurism is extirpated and a transplanted vein is substituted for the missing part of the artery (Goyanes' and Lexer's cases); and the method of grafting the popliteal artery, recently dissected from an amputated limb of another subject as a substitute for the diseased artery and aneurism previously removed by extirpation (Delbet's case) are interesting, but too hazardous to be regarded as anything more than surgical experiments or adventures, which at best are justifiable only in a limited number of very exceptional cases.

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(See also the references included in the text.)

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CHAPTER LXXI.

SURGERY OF THE FEMALE GENITO-URINARY ORGANS.

By E. E. Montgomery, M.D., John M. Fisher, M.D., and P. Brooke Bland, M.D.

Methods of Examinations and Diagnosis; Malformations, Etc.

By P. Brooke Bland, M.D.,
PHILADELPHIA.

MEANS AND METHODS OF GYNECOLOGIC EXAMINATION.

History Taking.—Before submitting a woman to a physical examination, it is extremely important that a careful clinical history of the individual should be procured. This is of value for several reasons:

In the first place, it permits the patient to become acquainted with the physician, and, as the result of a few moments' conversation, it allows her to regain her composure and calm, and thus prepares her for the physical examination to follow. Besides, during the collection of the clinical notes the physician is enabled, by close observation of the patient, to make mental notes as to her general condition. Furthermore, a complete history will be of the utmost value to the physician as a record for future reference.

Careful observation during the interrogation of the patient will furnish certain knowledge as to her general condition, such as the state of her nutrition, the condition of her nervous system, and many other points bearing upon her case. However, no definite plan can be applied to all cases, and it is well to vary one's plan of collecting case records according to the temperament and condition of the patient. Delicacy, tact, patience, and judicious questioning must always be employed, and the thoughts of the patient concerning her state should be respected.

At the beginning it is well to allow the patient to recite her version of her troubles, and, after a time, one may assume the rôle of interrogator and thus obtain a complete, intelligent, and permanent record of the case.

Special forms or blanks are recommended for recording the case history, and the card index system is highly commendable and is growing in favor.

The clinical history should always consist of the following data: Date of consultation; name of patient; residence; age; occupation; nationality; social state (married or single); family history.

Personal history, including the history of the functions of vital systems of body, namely: Nervous, circulatory, skin, digestive, respiratory, urinary, menstrual history, marital history, history of previous treatment, history of present trouble.

If specially constructed record tablets or blanks are used, spaces should be reserved for recording the result of the physical examination to follow and for notes of treatment instituted and recommendations made.

The Date of Consultation.—The recording of the date of consultation is important as a matter for future reference and from the bearing it may have on the appearance of the next menstrual flow, for instance: if, upon examination, conditions were such as to require operative interference, it would be well, though not absolutely essential, to conform one's plans so as not to conflict with that process.

Residence.—The place of residence should be recorded, not only as a business matter, but in order to determine the possible influence of environment on the general health of the individual. The character of her home surroundings may have some bearing upon her condition; individuals who live in small, crowded, ill-ventilated houses, or in densely populated sections of the city, or inhabitants of swampy, malarial regions, are prone to develop pelvic disease.

Age.—The age of the patient is of the utmost importance, because of the maladies incident to the different seasons of a woman's life. Infancy and childhood, extending from the time of birth to the establishment of puberty, is a period when congenital defects of the genitalia are frequently revealed. Neoplasms developing during this period are usually benign in character. Infections of the genitalia (complicating the acute exanthemata frequently develop during this period; specific infection, particularly in little girls housed in institutions, is not an uncommon occurrence. Malformations may pass unnoticed during this period, but, with the establishment of puberty, these conditions are usually disclosed. Inflammations developing at this time may extend to the pelvic viscera, but are, as a rule, limited to the lower part of the genital canal, and rarely reach the uterus.

During the child-bearing period conditions resulting from congenital defects may first be discovered. Inflammations of the more serious and destructive types occur, and extend to and involve the internal organs. Lesions resulting from pregnancy and labor, such as lacerations and displacements, occur at this time. Neoplasms of all types develop during this period, but the most frequent are those of benign character.

With the establishment of the menopause, the predisposition of malignant growths to develop should be constantly borne in mind, and no abnormal condition, arising during this period of a woman's life, should be lightly regarded. The terms: "You are entering the change" or "passing through the change" or "the symptoms you complain of are to be expected at this time," are too frequently employed by the general practitioner, and often with dire results to the patient. Any unusual symptom, arising at this period, calls for a careful and painstaking pelvic examination, and the surgeon who fails to institute this procedure is not doing his full duty to his patient.

The changes in the pelvic organs in the latter years of a woman's life are those incident to senile conditions, and are manifested, principally, by so-called senile inflammation. This condition is most frequently found in the upper part of the vaginal canal, and, as a result of this process, marked distortion, narrowing, and even obliteration of this part of the vagina may take place. This is due to the contraction of the organizing inflammatory tissue. This process may also involve the cervical canal, causing a stenosis of this organ, resulting in an accumulation of secretions within the uteine cavity, dilating the organ and giving rise to the formation of a hydrometra, pyometra, or hematometra, according to the character of the material imprisoned. Frequently women who have suffered for a long period with pelvic disorders enjoy a period of comparative freedom from these conditions at this time.

Occupation.—Occupation plays an important rôle in the etiology and aggravation of gynecologic affections. Young girls, confined to institutions, schools, and convents, with improper exercise in the fresh air, all suffer, more or less, with pelvic disturbance, and women who are crowded in poorly ventilated and unsanitary factories and workshops, with poor food, arduous duties in cramped and unhealthy positions, are prone to develop pelvic diseases.

Nationality.—The African race is more frequently afflicted with fibroid tumors than any other race. It is said that 20 per cent. of colored women who reach the age of thirty, and that 40 per cent. of those who reach the age of forty years, are afflicted with neoplasms of this type. The Caucasian, however, is more likely to be afflicted with neoplasms of a malignant character. The Jewish race forms a great proportion of the work of the gynecologist. This is especially true of the poorer classes, and the gynecologic clinics of the hospitals in the large cities derive a great percentage of their work from women of this race. The cause of this condition is explained by the congested and unsanitary manner in which they live, by the careless preparation and scanty supply of food, and from improper attention during pregnancy and labor, a great proportion of Jewish women being attended, not by skilled physicians, but by the uncleanly, careless midwife.

Social State.—The social life of the patient should be carefully

interrogated. It is important to determine whether the patient is single or married. This information will frequently save the physician from making embarrassing blunders in asking questions. Physicians are often prone to draw hasty conclusions concerning pelvic disease in single women, but this phase of the patient's life, while at times suggestive, should never mislead the doctor, and he should make his diagnosis only after careful physical examination.

Family History.—Heredity does not play an important part in the causation of pelvic disorders of women, yet a family history of tuberculosis, mental disease, blood dyscrasia, and malignancy should not be underestimated; however, one should never be too greatly influenced by it.

Personal History.—The personal history should include careful questioning concerning previous illnesses, such as acute infectious diseases, injuries, anemias, and all other conditions that might have some possible bearing upon the case. The condition of the patient's nervous system should be ascertained. She should be asked regarding headache, and this should include information regarding its character, time of occurrence, location, and duration. The question of sleep should also be considered; whether she is troubled with nervous irritability; symptoms of hysteria and neurastheina should be noted and recorded; neuralgias, their location and character; mentality, as to memory, should be inquired into. She should be asked about the condition of her circulation, whether she is troubled with hot flushes, perspiration, and palpitation of the heart. Questions concerning the skin should also be asked, as to the presence of eruptions (character and site), whether troubled with pigmentary deposits, their character and location. The condition of the gastro-intestinal canal should also be considered, such as her appetite; whether she is troubled with nausea and vomiting; if so, the time of its occurrence the character of the material vomited, whether associated with pain, and whether related to the ingestion of food. The condition of the bowels should be inquired into, as to diarrhea, constipation, bleeding, presence or absence of hemorrhoids, protrusions from the bowel, and painful defacation. The urinary system should also be included, as to frequency and freedom of urination; whether painless or associated with pain; if so, its time and character. The respiratory functions should also be included.

It is important to ask concerning the functions of all vital systems of the body, for the relation they may bear to the existing pelvic trouble. It is well to remember, in this connection, the profound influence that disease of the pelvic organs exerts on the general systems of the body, and that, frequently, abnormal symptoms arising in these systems may completely overshadow the local pelvic symptoms and lead the physician to err in a correct interpretation and diagnosis of the pelvic lesion. It is not unusual to find women to have been treated for "heart disease," "nervousness," constipation, hemorrhoids, anemia, gastritis, indigestion, dyspepsia, kidney disease,

catarrh of the bladder, and many other ailments, when the true cause of the trouble consisted in some derangement in the organs of the pelvis.

It is well to remember, too, that diseased states of the vital systems of the body frequently give rise to marked disturbance in the pelvic viscera, and it behooves the examiner, therefore, to consider carefully the relationship these systems bear to the generative organs, and vice versâ, before establishing a positive diagnosis.

I feel that it is wise to warn the physician not to attribute every abnormal disturbance in the great systems of the body to some minor pelvic condition; this is too frequently done. I would emphasize the importance of always making a careful pelvic examination in women who manifest some of the functional disturbances mentioned, before deciding upon a diagnosis.

Menstrual History.—The menstrual history should begin with the recording of its advent. The menstrual flow is usually established earlier in women of the blond type, in those of warmer climates, and in the city-bred girl. The regularity of the recurrence of the menstrual flow should be ascertained. As a rule, the process recurs every twenty-eight days, and this is regarded as normal. However, a variation of one or two days is not of special significance; indeed, it may be normal for certain individuals to menstruate every twenty-one days, while others may go a few days, or even a week, over the usual period without any ill effects. The duration, quantity, and character of the flow should next be considered; usually, it lasts from two to eight days, the average being about five days. The quantity of blood normally lost is said to be from three to nine ounces, depending upon the type of the individual; the average loss is about six ounces. The duration of the flow and the quantity lost do not depend entirely upon the type of the woman. Small, healthy women may lose considerably more blood than large, obese women. Indeed, we frequently find that, in the latter, the flow may only last a day or two, being a scanty, pale colored, scarcely perceptible discharge. The estimation of the quantity by means of napkins is unreliable, because of the variations in the habits of women regarding cleanliness; as a rule, three or four napkins are used in twenty-four hours—some women use more, some use less.

The menstrual flow is generally thin, and of a bright red or of a reddish-brown color, and coagulates very slowly, the coagulability being delayed by the alkaline reaction of the uterine secretions. Rapid coagulation of the menstrual flow is always regarded as abnormal, and the passage of clots is indicative of the retention of the fluid within the uterine cavity for a sufficient time to allow clotting to take place. Coagulation may be caused by the presence of polypi, fibroid tumors, endometritis, carcinoma, and retained products of gestation.

When the flow is a sort of a syrupy substance, it is supposed to have remained a long time within the uterus, and the presence of tissue fibers in the flow is suggestive of the existence of degenerating

neoplasms. The date of the last menstrual flow is especially important for the bearing it may have upon the presence of pregnancy, and this phase of the menstrual history should always be obtained and recorded. The date of the total disappearance of the menstrual flow should also be investigated. As a rule, it is a variable one. The complete cessation of this process is spoken of as the menopause, change of life, critical period, turn of life, and climacteric. In about 50 per cent. of women the menopause is established between the forty-fifth and fiftieth year; in 25 per cent., between the fortieth and forty-fifth year; in 12.5 per cent., before the fortieth, and in about 12.5 per cent. after the fiftieth year. In a few cases it may occur between the twentieth and thirtieth year, or as late as between the sixtieth and seventieth year. These late periods have been mentioned, but it is questionable if they were physiologic. It is very unusual to find a woman in normal health menstruating after she reaches the forty-fifth year. The total disappearance of menstruation may take place abruptly or slowly. Its duration generally is from one to three years. The normal menstrual life of the woman, therefore, is about thirty-five years. Undue prolongation of this process should always be regarded with suspicion, and, if possible, its cause should be ascertained by a careful pelvic examination.

Disturbances of Menstruation.—Profuse and prolonged menstrual flow is spoken of as menorrhagia, and is regarded as abnormal.

The causes of this condition may be classified into general and local, the general causes being diseased conditions of the cardiovascular system, chronic diseases of the lungs and liver, and certain blood conditions, such as pernicious anemia and hemophilia. Menorrhagia also occasionally complicates some of the acute infectious diseases, and this is particularly true of typhoid fever.

The local causes may be due to lesions of the vulva, such as inflammations, ulcerations, traumatisms, and new-growths. The same conditions may exist in the vagina, in the uterus, in the Fallopian tubes, ovaries, and peri-uterine tissues. The conditions complicating pregnancy and the puerperal period as a cause of bleeding should be kept in mind, and the possibility of an extra-uterine pregnancy as a cause should always be remembered.

Bleeding between the normal menstrual periods is called metrorrhagia. This is wholly an abnormal process. The classification of the causes and site of this condition are the same as those mentioned under Menorrhagia.

Amenorrhea is a term applied to an absence of the menstrual flow. The cause of this may be both physiologic (as in pregnancy) or pathologic and local or general, the general causes being any condition that lowers the patient's general health, such as tuberculosis, anemia, and malnutrition. Amenorrhea is frequently present in individuals recovering from severe illnesses. It is also commonly found in young women who are confined to institutions, such as schools, convents, and unsanitary workshops. The local causes of amenorrhea may be the

existence of some congenital malformation of the genitalia, such as stenosis of the cervical or vaginal canals or an imperforate hymen, imprisoning the menstrual flow within the uterine or vaginal cavities.

Menstruation associated with pain has been described as dysmenorrhea. In a certain number of cases no pain or discomfort is experienced, but, in the great majority, more or less disturbance is complained of. The pain may be of a dull, aching, bearing-down, labor-like type, or it may be sharp, shooting, and lancinating in character, and may be so severe as to confine the patient to bed. The pain may be located in the back or loins or over the region of the lumbosacral joint. It may also be situated in the pelvis, over the pubic joint, or may radiate down the posterior aspect of the thighs.

The consideration of the time of pain is regarded with special significance by some authors. Pain preceding the menstrual flow by one or two days is said to indicate a diseased state of the ovaries. Pain accompanying the flow is regarded as of uterine origin, and pain following the cessation of the flow is considered indicative of tubal disease.

In ascertaining the menstrual history the patient should be questioned concerning discharges taking place between the menstrual periods, and discharge other than blood occurring during this time is called leukorrhea. This condition is generally termed "the whites." Leukorrhea may have its origin in any part of the genital tract from the vulva to the peritoneal cavity. The most common form of leukorrheal discharge is a thick, tenacious, white-of-egg substance, and is caused by inflammatory action of the glands of the cervix. It may be of a creamy consistence or yellow or greenish in color, due to the presence of pyogenic germs. It may also be of a thin, watery character, indicating inflammatory disease of the endometrium. This condition has been called hydrorrhea. Between the menstrual periods the discharge may be somewhat scanty, increasing just preceding the flow or following the cessation of that process. It may be very profuse and constant, and extend over a long period of years.

The causes of leukorrhea may be divided into local and general, the general causes being conditions that lower the normal state of health of the individual, such as poor nutrition, overwork, unsanitary surroundings, improper application of wearing apparel, and indifference to hygienic principles. The local causes may be due to inflammatory or eruptive diseases of the vulva, ulcerations, and tumors, and these same conditions as causes may be applied to the organs of the pelvic cavity.

Marital History.—The marital history should comprise the date of marriage, whether early or late in life, because this feature may have an important bearing on the development of diseased conditions in the genital organs.

The number of pregnancies should include the number of normal, full-term, and premature labors. If the surgeon asks only the number

of children the patient has had, the history of premature births or abortions may be overlooked, because women, as a rule, try to conceal their miscarriages. Therefore the number of pregnancies should be ascertained, whether the children were all born at full term, or whether some were premature; the date of the first and each succeeding labor, including the date of the last, should be recorded. The condition of the patient during her pregnancies, as to complications, should be inquired into; the character of the labors as to duration; instrumentation and convalescence should all be carefully considered. Concerning the premature births—their time of occurrence, time confined to bed, cause, and recovery; whether associated with pain and fever; or whether surgical interference was instituted, should all be carefully noted. Lactation has a most important bearing on certain diseases; one should know whether the patient nursed her children and for what length of time.

The marital history should further include a record of the relation of husband and wife, but this should be secured with great caution and delicacy. Coitus must be inquired into in a certain number of cases, and the frequency of the act should be elicited, and whether it is associated with pain (dyspareunia). This condition is a most important one in relation to the happiness and health of a woman. The causes of dyspareunia are awkward or ineffectual attempts to perform the act of coition; disproportion in the size of the male organ and the vagina; faulty development of the female parts; inflammatory processes in the vulva, vagina, cervix, uterus, Fallopian tubes, ovaries, peritoneum, cellular tissue; displacements of the uterus or ovaries, urethral caruncle, tender carunculæ myrtiformes, vaginal fissures, ulcerations, vaginismus, coccydynia, hyperesthetic nerves, neuromata, and fear on the part of the patient.

The marital history should also include a record of the methods employed to prevent conception. This question women frequently evade, and those who practise it will usually endeavor to deceive the doctor. Whether the patient has or has had syphilis, and especially, if married, whether she may have contracted it from her husband, should be inquired into. Sometimes the husband will afford the requisite facts, but often the wife is our only source of information. In such cases great care and tact must be used to get at the facts without arousing the wife's suspicions. We can ask whether she has suffered from sore throat or had any severe inflammation of the eyes, any eruption over the body, or if her hair has fallen out or if she has had any spontaneous miscarriages. The teeth, both her own and her children's, should be examined. The possibility of gonorrheal infection should also be kept in mind, and the patient should be questioned concerning the absence or presence of discharge. If present, its relation to intercourse should be ascertained. Its amount, color, character, consistence, and whether associated with pain and burning, especially during urination, should all be elicited.

Present Trouble.—The clinical history should also include an

outline of the existing trouble. The time of the appearance of the symptoms; the character of the symptoms, the possible cause, aggravation, whether increased or intensified by exercise, etc., should all be recorded.

After the collection of the above data, the patient should be then informed that, in order to make a positive diagnosis of her trouble, a careful physical examination is necessary.

Physical Examination.—During the collection of the case history the patient should be gradually led to realize that a careful physical examination will be necessary in order to arrive at a correct diagnosis. No greater error can be made, on the part of the surgeon, than abruptly and brusquely to inform the patient that an internal examination must be made.

While collecting the case record, very great caution should be observed in asking questions, and the physician should employ every means to secure the confidence of the patient and quiet her timidity and nervous fear. One should always be mindful of the fact that an internal examination is a source of great distress and a trying ordeal to the woman who is not an habitual visitor to the doctor's office. The physician should consider it his bounden duty to respect the sensibilities of his patient, and shield and protect her from all unnecessary exposure.

A complete gynecologic examination should include: first, a general examination of all the vital systems of the body. One should never be hasty, as is too frequently the case, in attributing a group of certain general symptoms to some pelvic lesion without making a pelvic examination to substantiate this opinion. The systematic examination of every important organ of the body impresses the patient and makes her feel that she is in safe and competent hands.

The general examination should comprise an investigation of the nervous system—*i. e.*, testing the reflexes and examining areas of hyperesthesia, hypesthesia, and hysterical stigmata. The condition of the heart and lungs should also be carefully investigated. The urine, preferably a catheterized specimen, should be physically, chemically, and microscopically analyzed, and, in many cases, a thorough examination of the blood should be made.

One of the most important phases of the general examination is a careful observation of the general condition and deportment of the patient; the general appearance and nutrition should be observed; the character of the skin should be noted, whether she is pale or anemic, rosy-cheeked and plethoric, or apathetic and cachectic. Pigmentations and eruptions, if present, should be also examined. The physician should note, while the patient is walking or standing, whether locomotion is normal or whether any deformities exist in the spine, pelvis, or lower extremities.

After the completion of the general examination, which may successfully be accomplished in the consulting room, the patient should be prepared for the examination of the abdominal and pelvic

viscera. This should include an external and an internal examination, a combined examination, rectal examination, vesical examination, instrumental examination, examination under anesthesia, and, in obscure cases, the above may be associated with dilatation and digital exploration of the uterine cavity, test curetment, test excision, bacteriologic examination, x-ray examination, and exploratory incision.

Preparation of the Patient.—The physician who practises gynecology should provide a suitable room for this type of work. The room should be well lighted, heated, and ventilated, and should be provided with a toilet room. The preparation for a local examination, whenever possible, should be placed in the hands of a tactful and intelligent trained nurse. This is important for the reason that the patient will derive additional comfort and security by the nurse assuring her that every effort will be made not to expose her unduly and that means will be taken not to inflict pain or discomfort. Moreover, the presence of the trained nurse or a third party may be a most important source of protection to the surgeon against the unscrupulous blackmailer.

The duties of the nurse should consist in removing and arranging the patient's clothing and in seeing that the bowel and bladder are completely empty. Nothing is more trying to the physician than to find the patient on the table with her clothing suitably arranged, and, on introducing the examining finger into the vagina, find the bladder greatly distended or the rectum filled with fecal matter. A correct interpretation of pelvic disease cannot be made if such a condition exists, and it would be greatly embarrassing to the patient to have her visit the toilet after all other preparations have been made. If possible, the examination should be arranged for in advance, and the patient be instructed to have the bladder and bowel empty.

The nurse should carefully place the patient on the examination table. After the patient is placed in the proper position upon the table, the clothing should be removed from the abdomen and a clean white sheet should be placed over the pelvis and lower extremities, and another over the thorax and upper abdomen. The sheets should join in the midabdomen; these can be easily separated by the surgeon when the examination begins. If the external parts are soiled by discharges, they should be cleansed by the nurse with warm boric solution, and if a vaginal discharge exists, the patient should receive a warm vaginal douche.

Before beginning the external examination the physician should carefully cleanse and warm his hands, and the nails should be trimmed short and made smooth. As a rule, and in *all* cases of possible cancer, syphilis, and gonorrhea rubber gloves should be worn.

The patient should be placed upon her back, with the head slightly elevated on a pillow, and, at first, the extremities may be extended.

The examination should begin with a careful inspection of the

breasts: their size, color, and condition of the nipples; the presence of general or local swellings, and while palpating these organs for tender areas or enlargements, pressure should be made with both hands from the periphery toward the nipple, in order to determine the presence or absence of secretion. The condition of papillæ around the nipples should also be investigated, and the presence or absence of pigment should be noted. Frequently the breast examination may be incidentally carried on during the general examination of the chest.

Next there should be a general systematic inspection of the anterior abdomen. The condition of the skin should be observed; if it is pigmented, note its site and character. The presence of lineæ striatæ, whether old or recent, due to overstretching of the abdominal walls by pregnancy or intra-abdominal tumors, fluids, etc., should be ascertained. The nutrition of the parts whether thin and flaccid or fatty and pendulous, should also be observed. The general contour of the abdomen should be noticed—whether large from side to side; whether the enlargement changes with the position of the patient; whether the enlargement is prominent in the median line; if so, its character; whether regular and smooth, as in pregnancy and ovarian cysts, or irregular and nodular, as in fibroid tumors. The condition of the recti muscles should be noted—whether bulging takes place in the median line on straining. Observation should be made of the umbilicus, whether retracted, distended, or the seat of secretion or dirt; the veins, whether normal or prominent, and distended, as in ovarian tumors, pulsations of the aorta, fetal movements, or intestinal peristalsis. The results of respiration on the abdominal contents may be seen, and the presence and character of discolorations and eruptions may be determined.

Abdominal Palpation.—For the performance of abdominal palpation the patient should be placed, first, upon her back, but if it is desirable to note the influence of change of position on the contents of the abdominal cavity, the erect, lateral, or knee-chest position may be utilized. In all instances the examination should be made in a careful and systematic manner. The abdomen may be geographically outlined into four quadrants, and each quadrant should be palpated methodically. As stated in a previous paragraph, the hands of the examiner should be warm, and the finger-nails cut short and made smooth. Both hands should be used, and the pressure made should not be digging and penetrating, but with the palmar surfaces of the fingers, and in as gentle a manner as possible. The attention of the patient should be distracted from the hands of the examiner by asking questions concerning some other portion of the body, and she should be instructed not to resist, but to relax and breathe deeply with her mouth open.

Palpation should first begin in the upper abdomen, and the presence or absence of rigidity, tenderness, or abnormal prominences should be elicited. The condition and consistence of the abdominal

walls, whether thick, fatty, or flaccid and relaxed, should be determined. If tenderness is manifested, one should determine its true nature and possible origin, whether due to nervousness or organic trouble. If the patient complains on slight pressure, her mind should be occupied by asking questions, and if deep pressure is tolerated, one is justified in excluding inflammatory trouble. The viscera of the right hypochondrium should be palpated, and the condition of the gall-bladder determined. The mobility of both kidneys, especially of the right, should be examined by requesting the patient to take a long deep inspiration with the thighs flexed upon the abdomen. If the lower pole of the organ is felt to emerge below the margin of the ribs, the condition should be regarded as physiologic; if the kidney should reach a lower level on deep inspiration, undue mobility is present. The umbilicus should be palpated in order to determine whether it is patulous or the seat of a hernia. The recti muscles should be palpated in order to determine the presence or absence of rigidity, tenderness, and whether they are separated and in a state of diastasis.

Palpation will reveal the thickness of the abdominal walls, the presence of tumors and accumulations (their size, shape, mobility, consistence, possible character, number, and origin). Fat in the abdominal wall is frequently confounded with intraperitoneal growths, but this substance can be raised or lifted up in great folds, and thereby be differentiated. Tumors of the abdominal walls move with the walls, and may be lifted up with the tumor. Fetal parts and fetal movements may also be felt.

Percussion.—Percussion is employed as an auxiliary to palpation. It is chiefly used to distinguish the tympanitic note of the stomach and intestines and the flat sound over a tumor or an accumulation of fluid. Tumors in close contact with the abdominal wall are flat on percussion. In exceptional cases, where there is gaseous decomposition of an ovarian cyst or an ectopic gestation sac, the note is tympanitic. Tumors covered with loops of bowel may also give a tympanitic percussion-note. In ascites, providing the mesentery is unretracted, tympany is found in the median line, with dulness in the flanks. This is due to the intestines floating on the ascitic fluid. In ovarian tumors dulness or flatness is present in the median line, and tympany is elicited in the flanks and above the tumor, due to the crowding of the bowels into these locations.

Auscultation.—As a method of examination in gynecology, auscultation is of little value, except in the diagnosis and differential diagnosis of pregnancy. It is used more particularly for the purpose of eliciting fetal heart-sounds, fetal movements, and the uterine bruit. Other auscultatory phenomena are the intestinal noises and arterial sounds, but these have little or no bearing on gynecologic diagnosis.

Mensuration.—This method may be of value in the diagnosis of abdominal enlargements, and may be employed as a means of determining the rate of growth of an abdominal swelling. Exact measure-

ments are difficult to obtain on account of the variable degrees of distention of the intestine and of the abdominal tumor. Measurements may be taken by the ordinary tape-measure, and this may be made at the greatest circumference, the circumference at the level of the navel, and the distance from the ensiform cartilage to the pubes, also from the umbilicus to the anterior superior spine of the ilium on either side, and from the linea alba to the spines of the vertebræ. It is important that the same position should be assumed in taking all subsequent measurements for the purpose of comparison.

Vaginal Examination.—The statement frequently made that the routine inspection of the external genitals is unnecessary is erroneous, and should be condemned because lesions may exist in the external genitalia and vaginal outlet which may pass wholly unrecognized by the palpating finger. Indeed, in my judgment more information may be gained concerning the external structures and vaginal outlet by close inspection than by careless unobserved palpation. Not infrequently surgeons introduce the examining fingers into the vaginal canal without inspecting the external parts, and thus fail to discover congenital defects, lesions of Bartholin's glands, eversion of the vaginal walls, tumors about the vestibule and urethra, and many other conditions.

The external examination should never be considered complete without a close inspection of the parts. Inspection can, however, be instituted while the digital examination is being performed, and by this method the presence or absence of malformations, inflammations, eruptions, ulcerations, tumors, benign or malignant, edema, discolorations, lesions of the urethra, vaginal walls, perineum, and anus may be determined. The color, consistence, quantity, and general character of discharges will also be observed. For the performance of digital exploration of the vagina the patient should be placed in the dorsal position, and the external parts and extremities should be surrounded with clean white sheets or thin coverlets. Unnecessary exposure should be avoided. The surgeon should thoroughly cleanse and warm his hands, and the finger-nails should be closely trimmed and made smooth. If a profuse vaginal discharge is present, the parts should be cleansed with warm boric-acid solution, and, in certain instances, a warm vaginal douche should be given. If suspicious discharges or ulcerations exist, the physician should protect himself by the application of rubber gloves. Indeed, in my opinion it is best to use rubber gloves in all vaginal examinations. The bladder and rectum should have been thoroughly emptied, and the exploring finger, before being introduced, should be lubricated with olive oil or Castile soap and water. This latter method of lubrication has the advantage in that it does not soil the patient. The hips of the patient should be brought to the edge of the table, and the examiner should stand between her thighs, with his left foot resting on the steps of the examining table or on a suitable stool. The first two fingers of the right hand should be used, and the thumb,

avoiding the urethra, clitoris, and anterior tender structures, should ride over the curve of the groin, while the ring and little fingers should be extended and made to follow the curve of the perineum. By this means the perineum and coccyx are pushed upward and inward, thus allowing the further introduction of the vaginal fingers. Before introducing the examining fingers, however, the labia should be separated by the thumb and index-finger of the left hand. The examining fingers should be made to follow the posterior vaginal wall, and pressure anteriorly should be avoided. In virgins and in women with small, sensitive vaginal canals, the forefinger alone should be used. Digital exploration will reveal the presence or absence of congenital defects, tenderness, consistence of secretions, condition of the hymen, and the carunculæ myrtiformes, tonicity or degree of relaxation of the vaginal walls, condition of the vaginal rugæ, temperature, integrity of the perineum, presence or absence, size and consistency, of swellings and neoplasms, state of the urethra and the posterior bladder-wall and ureters, condition of the rectum, and the presence or absence of urethral, vaginal, or vulvar discharges. The shape, size, regularity, position, and mobility of the cervix may also be determined. The condition of the external os, whether the seat of lacerations, if so, their extent, and the presence or absence of nodules, tumors, or projections from the external os, may also be ascertained. Vaginal palpation will reveal the condition of the vaginal fornices as to depth, direction of curves, tenderness, rigidity, and induration. This procedure will also disclose the size, regularity, consistence, position, and mobility of the uterus, and conditions in the uterine appendages may be, in certain instances, recognized. The condition, however, of the organs above the vaginal fornices can best be determined by bimanual examination.

The Combined or Bimanual Examination.—This is the most valuable method of eliciting knowledge concerning the organs of the pelvis. Several different kinds of combined methods may be employed, such as the abdominovaginal, abdominovesical, abdominorectal, abdominovesicovaginal, abdominorectovaginal, and abdominovesicorectovaginal. The most commonly employed is the abdominovaginal, and this is the most reliable method of exploring the pelvic cavity (Fig. 106). In order to perform the abdominovaginal examinations successfully the vaginal canal must be comparatively roomy, its walls must be elastic or relaxed, and the depth of the canal must not be too great, as is frequently the case in large, obese women. Besides the above, the abdominal wall must be thin, relaxed, and free from tenderness. In individuals with thick, fatty, pendulous or rigid, resisting, tender abdominal walls, the bimanual procedure cannot be satisfactorily performed without an anesthetic. Indeed, in my judgment, it would be better to employ an anesthetic in the great majority of pelvic examinations. Some of the shorter anesthetics, such as nitrous oxid, ethyl bromid, or ethyl chlorid, may be used. These, however, do not entirely overcome resistance and rigidity, and

the latter agent is not without danger. If there are no contraindications, I feel that short chloroform anesthesia will afford the best service. The bimanual method is best performed with the patient in the dorsal position. The general preparation of the patient and hands of the examiner should be the same as that described in the preparation for the simple vaginal examination. The labia should be separated with the thumb and index-finger of the left hand. Two fingers of the right hand are then introduced into the vagina. The palmar surface of the left hand is then made to compress the abdominal

FIG. 106.—SHOWING POSITION OF HANDS IN PERFORMANCE OF THE ABDOMINOVAGINAL EXAMINATION.

wall, beginning above the umbilicus, and gradually working downward toward the pubic joint. The pressure should be light and gentle, in order not to excite the abdominal muscles to contract. If there is a tendency to nervous spasm or rigidity of the muscles, the patient should be directed to breathe gently with the mouth wide open. She may also be advised to take long, deep inspirations and then allow the air slowly to escape. By these means deep palpation may successfully be accomplished. It is important to remember that the abdominal hand should not exert pressure immediately behind the symphysis,

because in so doing the position of the uterus may be changed and an erroneous diagnosis made.

In every case the examiner should keep in mind the various organs and conditions to be investigated, and the examination should be conducted in a thoroughly systematic manner. Symptoms suggesting the existence of disease in a single organ should not lead the physician to direct his methods of examination to that organ alone, but each organ in turn should be investigated methodically. The bimanual procedure will reveal the condition of the vaginal walls, the presence or absence of tenderness, discharges, ulcerations, indurations, malformations, and tumor formations in that canal. By this method the sensibility, size, regularity, consistence, and mobility of the cervix may be determined. Combined examination will also disclose the exact position of the uterus, its size, regularity, consistence, mobility, and relation to surrounding organs. The Fallopian tubes may also be examined with regard to the same conditions. Ordinarily, the normal tubes are not palpable, except in women with thin, relaxed abdominal walls and distensible vaginal walls. They are then recognized as small, rounded cords between the examining fingers. When the Fallopian tubes are readily palpable, it usually indicates the presence of some pathologic process. Bimanual exploration will also reveal the condition of the ovaries as to size, shape, position, mobility, and consistence. In women with thin, relaxed abdominal walls, these organs may be palpated. They are recognized as small, oval, tender masses on each side of the uterus. The ligaments of the ovaries are not palpable. The pelvic peritoneum and pelvic cellular tissue may also be explored by the bimanual method, concerning deposits, collection of fluids, tenderness, neoplasms, adhesions, and old cicatrices. By the bimanual procedure the base of the bladder may be investigated and the presence or absence of distention, inflammatory deposits, tenderness, fistulæ, calculi, and tumors may be determined. The condition of the ureters may be recognized, and when these organs are enlarged, firm, and tortuous, tuberculous infection should be suspected. The rectal wall may also be examined with the vaginal fingers, and the presence of tenderness, fecal accumulation, inflammatory induration, fistulous tracts, adhesions, and tumors may be revealed. The depth and condition of the vaginal fornices can be determined, and the size and condition of the birth canal, as to deformities, may be ascertained. The abdominovaginal examination offers the best means of differentiating various forms of pelvic tumors, and by this method their location, size, form, mobility, consistence, rate of growth, and relation to surrounding organs may be ascertained. In the investigation of enlargements and tumors, in order to determine their relation to the surrounding structures, the method of Schultze may be employed to advantage. This consists in having an assistant elevate the tumor, by pressure through the abdominal wall, while traction is made upon the cervix with a double tenaculum. The

examiner, then, with two fingers in the vagina and the left hand pressing over the abdomen, may outline the pedicle of a growth and determine its origin and relation.

The Abdominorectal Examination.—This method of exploration (Fig. 107) is usually employed in virgins. It must be resorted to in congenital defects of the vagina, in vaginismus, where the vaginal canal is obstructed by tumors, and in case of an imperforate hymen. This method is also used in studying the condition of the coccyx, rectum, and rectovaginal septum. It offers the best approach to the organs above the vaginal vault. Exploration by this method will further reveal the condition of the rectal canal, the posterior vaginal walls,

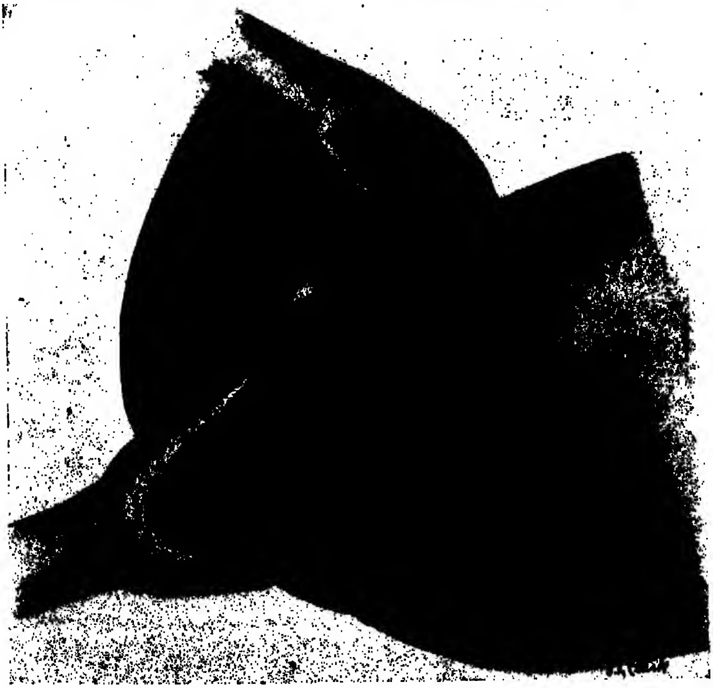

FIG. 107.—ABDOMINORECTAL EXAMINATION.
Rectal finger palpating a small subserous fibroid tumor.

cervix, posterior and fundal surfaces of the uterus, uterosacral ligaments, broad ligaments, Fallopian tubes, ovaries, posterior wall of the pelvis, and the possible character of pathologic processes that may arise in these structures.

The abdominovesical, abdominovesicovaginal, and abdominovesicorectovaginal examinations are used principally to investigate lesions of the bladder, but these methods are rather infrequently employed. It is important to remember that the performance of the bimanual examination must always be conducted with extreme care. This is especially true in the presence of the acute inflammatory conditions, in distended pus-tubes, in ectopic pregnancy, in

thin-walled ovarian cysts, and in cases of advanced cervical carcinoma.

Rectal Examination.—The examination of the pelvic structures through the rectum should be made in all difficult and unsatisfactory vaginal examinations. The conditions calling for the employment of this method are a congenital or acquired absence or atresia of the vagina, a narrow, shallow, rigid, tender vaginal canal, tumors filling the vagina, vaginismus in virgins with intact hymen, and in procidentia and in inversion of the uterus. This method may be employed with the patient in the Sims', the knee-chest, or preferably the dorsal position. The index-finger should be used, and it should be lubricated with olive oil or Castile soap, and introduced into the rectum with a rotary movement. The conditions revealed by this method are the tonicity and integrity of the sphincter muscles, the presence of abscence of fissures, polypi, hemorrhoids, and new formations. The structure of the posterior vaginal wall, cervix, posterior uterine and fundal wall, the tubes and ovaries, when enlarged and prolapsed, the base of the broad ligaments, may be investigated. Through this channel the condition of the sacrum and coccyx can be ascertained. It has been stated that the index-finger is generally employed in the performance of this method, and this will give satisfactory results. Simon has recommended the introduction of the entire hand, but this procedure is almost never indicated, and never should be used by a surgeon with a large hand. It is not without danger, and, therefore, has been largely discarded. Instrumental examination of the rectum may be made by the various forms of rectal specula, but the best instrument to employ is the proctoscope. This has the advantage that the rectal canal may be distended or ballooned with air, thorough illumination can be secured, and complete exposition of the rectal mucosa obtained.

Vesical Examination.—Many methods are used for the purpose of investigating the state of the urethra and bladder. Frequently ordinary inspection of the external orifice of the urethra will reveal the cause of vesical irritation, such as eversion of the urethral mucosa, urethral caruncle, and infection about the meatus and the openings of Skene's glands.

The performance of the bimanual examination frequently enables the surgeon to ascertain facts regarding the consistence, sensitiveness, mobility, and relationship of the bladder and the ureters. Palpation through the anterior vaginal wall will also disclose the presence of induration of the base of the bladder, and, by this means, vesical calculi may also be discovered.

The interior of the bladder may be investigated by the introduction of metal sounds, and this procedure would reveal the presence of any solid foreign body, particularly stones.

Dilatation and digital exploration of the interior of the bladder is occasionally employed, but not to the extent it formerly was. To-day this method is more or less obsolete, and is largely supplanted

by direct inspection of the bladder cavity through the speculum or cystoscope. Moreover, dilatation and digital exploration of the bladder is not without danger, and it is said that it cannot be performed in young girls or elderly women without great risk of permanent injury to the urethral canal, with possible incontinence of urine as a sequel, and, indeed, this unfortunate condition may occur in women between these age limits. Besides, in the great majority of instances, information derived from palpation of the interior of the bladder is inferior to direct observation.

Direct inspection of the cavity of the bladder may be obtained by the use of a small, tubular speculum, with reflected light or with a speculum containing an electric light in the vesical end. By the use of these instruments the bladder is distended with air, and thus a complete exposition of the vesical mucosa is secured. In this procedure a general anesthetic, as a rule, should be employed, and scrupulous antisepsis should be observed. The best position is the elevated dorsal or lithotomy posture, although the genupectoral may be utilized with advantage in certain cases. Before the introduction of the speculum the urethra should be dilated by the ordinary graduated bougies or the graduated cylindric specula may be used for this purpose. The most satisfactory method of examining the interior of the bladder is by means of the cystoscope. This subject has been fully discussed in Vol. IV., p. 285.

Instrumental Examination.—The principal instruments used in a gynecologic examination are the speculum, the tenaculum, and the sound.

The vaginal speculum may be composed of wood, glass, hard rubber, or metal. Glass specula are very rarely employed to-day, because of the danger of breaking. Specula composed of metal are chiefly used, and they may be several varieties, such as the tubular or cylindric, univalve, bivalve, trivalve, and quadrivalve. The bivalve, however, is the instrument most commonly employed. It is constructed so that the posterior blade is longer than the anterior, on account of the great length of the posterior vaginal wall, the posterior wall being about one-half inch longer than the anterior.

These instruments are used for direct inspection of the vaginal portion of the cervix and upper part of the vaginal walls; they are also used for the purpose of applying treatment to these structures. The dorsal position is usually employed for the introduction of the speculum, though the univalve, or Sims', speculum serves better with the patient in the lateral position. This instrument is used largely to expose the upper part of the anterior vaginal wall.

In the introduction of the vaginal speculum every precaution should be taken in regard to cleanliness and gentleness. The thumb and index-finger of the left hand should separate the labia and the blades of the speculum, pressing upon the posterior vaginal wall, and should be introduced parallel with the opening of the vulva. The instrument should be gently carried upward for a short distance, and then turned

with the blades horizontal, pressure being constantly exerted on the posterior vaginal wall, and avoiding the delicate anterior structures. If the vaginal walls are relaxed and protrude between the blades of the speculum, retractors should be introduced to hold the walls of the vagina apart. If the cervix is in close apposition with the posterior wall and is not readily exposed to view, elevation of the outer end of the speculum toward the pubes will frequently deliver the cervix between the blades of the instrument. If this fails, the cervix may be grasped with a tenaculum and drawn forward.

Too much emphasis cannot be placed upon the importance of thorough sterilization of the instruments before introduction, because infections are frequently transmitted by the careless employment of this instrument.

The Tenaculum.—The double tenaculum is used in gynecologic examinations to deliver the cervix into view for close observation and treatment. It is also employed to determine the extent of relaxation of the vaginal walls and the ligaments that support the uterus, and to ascertain the degree of mobility and the position of that organ. The double tenaculum is also utilized in drawing down the uterus in order to determine the relation of tumors attached to that organ, such as pedunculated subserous fibroids and ovarian cysts.

The **uterine sound** has been recommended for the purpose of ascertaining the size and position of the uterus, to measure the depth of its cavity, and also to replace displaced uteri. Those instruments were formerly used very extensively and carelessly, and, no doubt, were responsible for a great amount of harm.

Their dangerous character has, within recent years, been recognized, and, fortunately for our patients, they have been very largely discarded. The sound should always be used with the utmost care. Its introduction should be regarded as a surgical operation, and every precaution should be taken to guard against infection. Its careless and indiscriminate use in general office practice should be condemned. Before introducing the sound the surgeon should determine the position of the organ by bimanual examination, in order to avoid perforating the uterine wall. The instrument should always be introduced in the direction of the position of the uterus. The date of the last menstrual period should be elicited, in order not to interrupt a possible pregnancy. The sound should not be used if the uterine cavity is the seat of infection or malignant disease, nor should it be employed in the presence of suppurative disease of the appendages.

Dilatation and Digital Exploration of the Uterine Cavity.—Frequently the employment of the methods of examination we have thus far described will fail to reveal the presence and character of intra-uterine disease, and we are compelled to employ other means. The identification of uterine disease may be made by dilating the uterus and exploring its cavity with the finger (Fig. 108). This procedure should be regarded as of the same importance as an ordinary dilata-

tion, and the same antiseptic precautions should be observed. General anesthesia should be employed. The uterine cavity may be dilated by the parallel bars, Pratt's graduated bougies, or laminaria tents. The parallel bars, however, usually inflict more or less injury, and thereby disturb the cell relation and character of any existing growth. The graduated bougies may be used with safety, but the laminaria tents afford the best service. By their use a higher degree of dilatation is obtained and the cervix is gradually thinned out, rendered elastic, and will thus allow the free introduction of the finger without constriction and impairment of the sense of touch. Digital exploration of the uterus will reveal the depth and direction of its canal, the

FIG. 108.—DIGITAL EXPLORATION OF THE UTERINE CAVITY.

character, thickness, and consistence of the endometrium, areas of friability, induration, retained products of conception, consistence of the uterine wall, and the presence or absence of projections and growths. It should be remembered, however, that microscopic examination is superior to digital exploration, and that the true character of intra-uterine disease cannot be positively determined by the palpating finger. A provisional diagnosis of a fibroid tumor may be made by finding a nodular, firm growth, and of carcinoma by discovering an area of friable tissue situated on a hard indurated base, but positive identification of any lesion can only be made by a microscopic examination. Digital examination of the uterine cavity should never be made without carefully eliciting the menstrual history

of the patient, in order to exclude the possibility of pregnancy. It should also be avoided in the presence of inflammatory accumulations outside the uterus, and it should always be executed with the utmost care.

Test Curetment.—In order to ascertain the true nature of endometrial and intra-uterine disease, sections of the tissue must be secured and submitted to microscopic examination. This is done by dilating and curetting the uterine cavity. The operation should be performed under general anesthesia. Every step of the procedure should be carefully executed, and the principles of surgical cleanliness should be rigidly observed. Dilatation may be accomplished by the parallel bars, gauze packing, laminaria tents, or graduated bougies. The latter instruments serve very well, and are not so likely to injure and distort the cellular architecture of the parts, and the operation should always be performed with this end in view. After a moderate degree of dilatation is obtained, the cavity of the uterus should be systematically curetted by the sharp angular douche curette. The operation should begin at a fixed point, and be carried out methodically in order to secure tissue from every part of the lining membrane. A good plan to follow would be first to scrape the anterior wall, then the posterior, then the lateral, and finally the fundus and angles. Long, successive parallel sweeps should be made from the fundus to the cervical opening, removing the membrane from the muscular structure. As the curetted material escapes from the uterus, it should be collected in a sieve of sterile paraffin paper. Careless handling must be avoided, and the collection of the tissue on a gauze pad should be condemned, as the tissue adheres to the gauze, and in its removal the individual elements are distorted, and the specimen is thus rendered practically useless. The macroscopic appearance of the curetted tissue should be noted, and the specimen should then be placed immediately in a fixing solution, and prepared for further examination. If it is desirable to make an immediate histologic diagnosis, teased or frozen sections may be prepared and submitted to microscopic examination.

Test Excision.—This method is superior to test curettement because it permits the removal of definite portions of tissue, which appear suspicious to the eye or the examining finger. It is, of course, available only when the diseased parts are accessible, and, therefore, can only be used in pathologic conditions of the vulva, vagina, and vaginal portion of the cervix. In the performance of test incision, the same general laws regarding antisepsis should be observed, as were advised in the operation of test curettement. The cervix is exposed by the introduction of Edebohls' speculum, or suitable retractors, and the lips of the cervix, free from disease, are secured with double tenacula and drawn well down until they are accessible to manipulation. The parts selected for excision should include both healthy and diseased tissues, in order to have the advantage of comparison. A wedge- or V-shaped piece of tissue should be removed

with a sharp, straight scissors or a scalpel. The wound left after the excision should be closed with one or more catgut sutures. The parts are then irrigated with a warm salt solution, the vaginal canal packed lightly with iodoform gauze, and a sterile perineal occlusive dressing applied. On account of the relative insensibility of the cervix, test excision may be performed without anesthesia. In the majority of cases, however, a general anesthetic should be given, although the operation can be successfully accomplished by the surface application of a 4 per cent. solution of cocain. Infiltration anesthesia will permit painless excision, but this procedure destroys the histologic cell picture, and hence should not be resorted to. Each step of the operation must be performed with the utmost delicacy, in order to preserve the normal cellular relation. This point cannot be too strongly emphasized. Unfortunately, many surgeons collect tissue in such a careless manner that by the time it reaches the microscopist's hands its structure is so altered as to render intelligent study almost impossible. After securing the tissue it should be washed in warm, normal salt solution, and then placed immediately in a good fixing fluid. If an immediate microscopic diagnosis is desired, the tissue may be examined as a teased specimen or by frozen sections. If haste is necessary, the latter method is preferable, because it interferes less with the cellular structure of the tissue and permits of a more correct judgment as to its character.

Bacteriologic Examination.—The importance of careful bacteriologic examination of tissues and secretions of the genital tract cannot be overestimated. The examinations are usually made by stained smears or spreads, but in certain instances cultures should be made and inoculations resorted to. Micro-organisms are found in the genital tract, but they are present only in small numbers, and, as a rule, in a low state of virulence. They are only found normally in the vulva, vagina, and cervix. The uterine cavity and structures above that organ, under normal conditions, are said to be germ free. The small number of pathogenic germs normally found are in a low state of infectiousness. This is due to several causes. The secretion of the vagina is highly acid, and is, therefore, not only an unfavorable medium for the propagation of germ life, but highly destructive to these bodies. Döderlein has demonstrated the presence of an acid-fast bacillus in the vaginal secretion, which he has shown to be antagonistic to invading pathogenic bacteria.

The absence of glands and of a submucosa in the vaginal walls does not provide suitable food and an abiding-place for germ life. The plug of mucus normally found in the external os is said by some authors to prevent to a certain degree the ingression of bacteria into the uterine cavity and the organs beyond. During menstruation, pregnancy, and parturition the secretion of the vaginal canal is neutralized, or rendered alkaline by the increased discharges from the uterus. During these periods, therefore, bacterial growth and extension are favored. The normal germicidal properties of the

vaginal secretion may be destroyed by excessive coition and constant vaginal irritation. Abrasions resulting from indelicate manipulation and operation also favor the propagation of germ life.

The parasites found in the genital tract are both vegetable and animal. The vegetable parasites are the most frequent, and include the staphylococcus pyogenes, streptococcus pyogenes, gonococcus, bacillus coli communis, bacillus tuberculosis, spirochæta pallida, the organism of chancroid, smegma bacillus, bacillus typhosus, bacillus pyocyaneus, bacillus aërogenes capsulatus, bacillus diphtheriæ, and the pneumococcus. The animal parasites are: the pediculosis pubis,

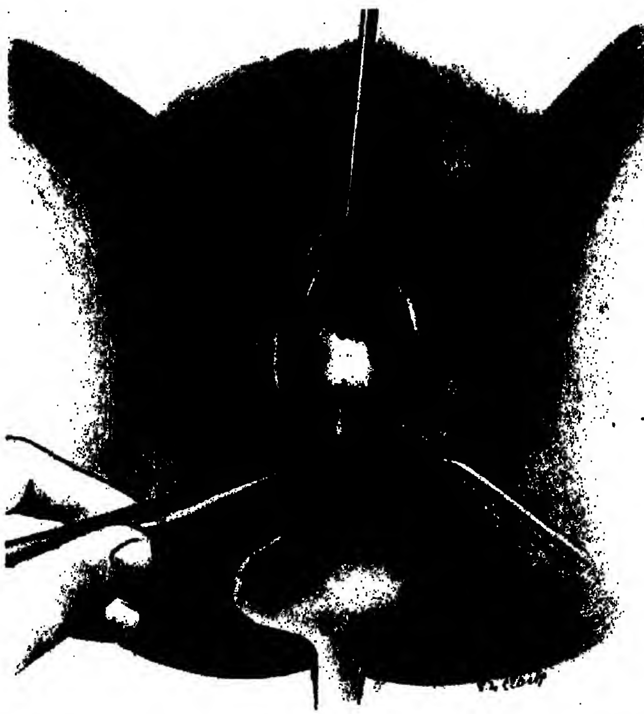

FIG. 109.—FIRST STEP IN THE PERFORMANCE OF POSTERIOR VAGINAL INCISION.

acarus scabiei, oxyuris vermicularis, ascaris lumbricoides, and tænia echinococcus.

Examination of Virgins.—An internal examination of a young girl or a young unmarried woman is a source of great annoyance, embarrassment, and terror, and, whenever possible the surgeon should refrain from making such vaginal examinations. Where the symptoms and signs call for a pelvic examination, the rectal route should usually be selected. The timidity and nervous fear of these patients may be overcome by the use of an anesthetic. Moreover, anesthesia enables the examiner to make a more thorough and systematic investigation of the pelvic organs. It would be distinctly

advantageous to administer an anesthetic in making all first-visit examinations.

Exploratory Incision.—With our present-day perfected methods of examination exploratory incision is seldom necessary. In obscure pelvic conditions this procedure may be resorted to. Should this intervention seem necessary, the patient's consent (often best in the presence of a witness or in writing, especially in the case of strangers) should be obtained, not only to make the incision, but to treat surgically any condition that it might reveal. Exploratory incision may be performed through the abdominal wall or through the

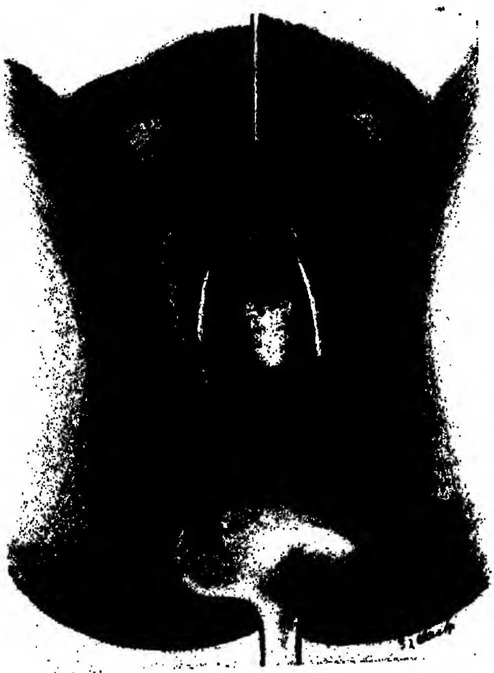

FIG. 110.—SECOND STEP IN POSTERIOR VAGINAL INCISION.
Showing incised vaginal wall and exposition of peritoneum with buttonhole opening.

posterior vaginal fornix. The latter route should be selected because it is easier of execution, is not a major operation, and is not associated with the pain, danger, and prolonged convalescence of an abdominal incision. Exploratory vaginal incision finds its chief usefulness in diagnosing positively a ruptured ectopic pregnancy, adhesions, distortions, and enlargements of the Fallopian tubes, the size, consistence, shape, and mobility of the ovaries, and lesions of the broad ligaments. The operation of posterior vaginal incision is performed as follows:

With the patient thoroughly prepared and anesthetized in the dorsal position, the cervix is exposed by the introduction of Edebohl's speculum. The posterior lip of the cervix is then grasped with two double tenacula and drawn downward and upward. Constant

traction is made with these by an assistant, who also retracts at the same time the posterior vaginal wall. The posterior vaginal wall, about one inch from its attachment to the cervix, is picked up with toothed forceps (Fig. 109), and a free incision (transverse or semilunar) is made through the vaginal wall from side to side (Fig. 110). The posterior edge of the incision is pushed back by blunt dissection, thus exposing the underlying peritoneum. This structure is then picked up and freely incised from side to side, thereby rendering free examination of the pelvic viscera possible (Fig. 111). Posterior vaginal puncture should never be performed, but the operation should be carried out by a free incision, as above described.

FIG. 111.—THIRD STEP IN POSTERIOR VAGINAL INCISION.
Showing incised vaginal wall and peritoneum and exposure of posterior uterine wall.

x-Ray Examination.—Examination by means of the Roentgen rays is employed as an auxiliary to the methods we have already outlined. The x-ray as a diagnostic agent is not of great value in gynecology, because our other methods of investigation are so complete that it is rarely necessary to resort to this agent. But the x-rays may be of value in revealing the presence of pregnancy. It will also disclose the presence of cartilage, bone, teeth, and calcareous deposits in dermoids and teratomata. It may also reveal the presence of calcified tumors, contents of old ectopic gestation-sacs, and foreign bodies in the bladder, ureters, and kidneys, and various deformities of the pelvis.

Catheterization.—There is no procedure in surgery so frequently performed as catheterization of the bladder, and it is, perhaps, from its frequent necessity that the cathether is so carelessly and indiscriminately used. The common saying, that "familiarity breeds contempt," certainly applies to the use of this instrument. It is not uncommon to find women who have made excellent recoveries from extensive vaginal or abdominal operations, suffering more from the prolonged and careless use of the catheter than from the operation itself. Its employment is regarded as one of the duties of the nurse,

FIG. 112.—POSITION OF HANDS IN CATHETERIZATION OF THE FEMALE BLADDER.

and it is sometimes difficult to impress upon them the dangers and complications that may accrue from its improper preparation and manipulation. Whenever possible, catheterization should be performed by or under the direct supervision of the attending surgeon. One must not only be mindful of the prolonged distressing symptoms and damage that may result from infection of the urethra and bladder, but of the possible extension of the infectious process to the ureters and the pelves of the kidneys.

The bladder may be emptied by the use of instruments composed of metal, rubber, or glass; the latter are preferable, because they are

more easily sterilized. These instruments should be boiled before and after using, and when not in use, they should be kept in alcohol or a 5 per cent. solution of carbolic acid. It is extremely important carefully to inspect the instrument before introduction to make sure that it is sound and free from rough cutting edges. Catheterization should always be performed under the guidance of the eye, and never by simple touch (Fig. 112). The patient should be placed, if possible, crosswise on the bed, with the thighs separated and flexed. The external genitals should be cleansed with a warm, weak solution of bichlorid, and if a profuse vaginal discharge is present, a preliminary douche of the same should be given. The parts should be surrounded with sterile towels, and the external meatus should be cleansed with warm boric-acid solution. The nurse, with her hands carefully prepared, should separate the labia with the thumb and index-finger of the left hand. The catheter should be grasped with the thumb and middle finger of the right hand, while the index-finger is held over the external opening of the instrument to prevent the premature discharge of urine. The catheter should then gently be introduced by passing it upward and backward, hugging the urethral floor. The entrance into the bladder will be manifested by the absence of resistance and the appearance of urine in the instrument. The occluding finger should now be removed, and the urine allowed to flow into a sterile receptacle. The bladder can be completely emptied by making pressure over the lower abdomen with the unoccupied hand. With the discharge of the last few drops of urine the finger should again be placed over the end of the instrument, to prevent the urine flowing over the vulva and soiling the bed. When pressure has been made over the abdomen, the finger should be so placed before the removal of the pressure as to prevent the aspiration of air into the bladder cavity. After withdrawing the catheter the parts should be again cleansed with warm boric solution and dried with a sterile towel or gauze. After an abdominal operation early catheterization should never be resorted to, but the patient should be given abundant opportunity and encouragement to empty the bladder herself. Directions should be given to wait, if possible, for twelve hours, but, of course, if the patient is distressed, catheterization should be used before that time. In plastic operations upon the anterior vaginal walls, providing the patient is unable to empty the bladder, the catheter should be used at the end of the sixth hour, because excessive distention of the bladder in these cases may destroy the object of the operation.

Catheterization of the Ureters.—Catheterization of the ureters has been considered in Vol. IV., p. 290.

CONGENITAL AND ACQUIRED ABNORMITIES.

HERMAPHRODITISM.

Hermaphroditism is "the coexistence, real or apparent, of male and female organs in the same individual." This condition in the human being is extremely rare, but it is normal in many plants and other forms of lower animal life. Hermaphroditism is divided into true hermaphroditism and pseudohermaphroditism. Notwithstanding the number of cases of true hermaphroditism reported, it is a question whether true blending of the organs of both sexes has ever occurred. Edgar and many other observers claim that there has never existed an individual who was provided with complete generative organs of the two sexes. Garrè operated upon a patient from whom he removed two small bodies from the pelvis which proved to be, on microscopic examination, testicular tissue. Another small mass near the testicle was removed from the same patient, and upon examination it was found to be composed of ovarian tissue. A Fallopian tube and a structure resembling the vas deferens were also present. Pseudohermaphroditism is divided into two types—the gynandrous and androgynous. These terms are used to indicate the special type of individual.

The gynandrous is a female with external genitals so formed as to bear some resemblance to the external organs of the male. In this type the general development and expression of the individual are decidedly masculine. The external genitals are markedly enlarged. The clitoris may be of such proportion as to resemble a penis, and the labia minora and majora may be extremely enlarged and fused together, so as to resemble a scrotum. Occasionally there is a hernia of one or both ovaries into the labia, making the resemblance to the male still more striking. The internal organs of these individuals are usually in a varying stage of development. In the androgynous class, the general characteristics, such as hair, facial expression, skin, speech, and general development, resemble those of women. The breasts may be large and well developed. The skin is smooth, delicate and free from hair. The external genitals resemble the female type, though they are, as a rule, poorly developed. In these persons the scrotum may be cleft, and there may be a failure of the testicles to escape or descend from the abdominal cavity. The penis may be small and resemble the clitoris. The presence of hypospadias makes the resemblance still more striking. There may also be small projections of skin along the scrotal cleft, suggesting the presence of the labia minora.

The treatment of hermaphroditism is a question of considerable importance. If the condition is discovered in childhood, the true sex should be determined, if possible in order that the individual may be reared accordingly. If there is any doubt as to the sex, the patient should be classed as a male, on account of the ability of males to acquire a living. Furthermore, the imperfect male is less likely

to marry. Operative measures should be instituted in certain cases if a doubt as to the sex exists, but operative correction of the external genitals should not be attempted without first determining the character of the internal generative organs by an abdominal operation, except where it is desirable to establish a new vagina for copulation.

MALFORMATIONS.

In the consideration of the anomalous type of faulty development that are found in the genital canal of the female it is well to recall that this structure is formed by the union of the Müllerian ducts, and that abnormal growth or non-growth of any portion of these organs will be responsible for different forms of maldevelopment that occur. Malformations arising in the genital canal are not uncommon, and we should always be on guard to detect their presence. The causes of maldevelopment are classified into the acquired and congenital. Acquired malformations of a serious type are rather uncommon, and are, as a rule, limited to the vulva, vagina, and cervix, though acquired deformity of the tubes and ovaries does occur. The acquired types result mostly from inflammatory processes, and as a result of inflammatory action in the vagina and cervix organizing bands of adhesions form in these structures, which frequently progress to contraction, and cause distortion and even obliteration of the upper part of the vaginal and cervical canals. Inflammation as a cause of acquired deformity in the vagina and cervix is frequently seen in women who have passed the menopause. Frequently in these individuals the vault of the vagina is found distorted and almost closed, and occasionally, from the same cause, atresia takes place in the cervix, which results in an accumulation of secretion within the uterine cavity. Acquired malformations may also result from lesions of labor, traumatisms, caustics, burns, and faulty operative work. Acquired malformations of the Fallopian tubes may result from inflammation, causing thickening, stiffening, and distortion of these structures. Inflammation about the tubes may cause the formation of adhesions, which contract and cause deformity of these organs. Tumors of the broad ligament and ovaries not infrequently cause marked elongation, twisting, and distortion of the tube. Acquired deformities of the ovary may result from inflammatory exudate about these organs, from organizing adhesive bands, and from the presence of tumors.

Congenital malformations may be due to:

Complete failure of the Müllerian ducts to develop.
Rudimentary development.
Irregular development.
Vicious development.
Precocious development.

Vicious development is exemplified in the various forms of congenital abnormal communications that sometimes form between the ducts of Müller and the urethra and bladder in front and the rectum behind. Precocious development is occasionally seen in newborn

infants. In these individuals the breasts are enlarged and may secrete fluid. The external genitals are markedly developed, and menstruation may occur. The individual in general is large and well developed.

Malformations of the Vagina.—Acquired malformations of the vagina, such as stenosis or atresia, are frequently caused by the lesions of labor. They may also result from the application of caustics, burning from irritating solutions, lupus, specific ulceration, cancer, and the long-continued irritation of a pessary. Stenosis is usually found in the upper part of the canal, but may occur in any portion. Congenital atresia may be found in different parts of the vagina, but this condition is generally found at the orifice, and is frequently caused by an imperforate hymen. Atresia of the vaginal canal, due to an imperforate hymen, or closure of the vaginal orifice from adhesions, may not be recognized until the establishment of puberty. At this period the patient will experience all the symptoms of menstruation, but without the escape of the menstrual flow from the genital canal. Instead of escaping externally, the flow gradually dilates the vaginal canal, and this may be followed by dilatation of the cervix and uterine canal. The fluid may even pass out through the Fallopian tubes, dilating these structures, and escape into the peritoneal cavity. With the progressive accumulation of the menstrual flow within the vagina, bulging of the imperforate hymen will take place, and later a bluish or purplish protuberance will appear at the vaginal outlet. Vicarious menstruation is not an uncommon phenomenon in these persons.

The accumulation of menstruation in the vagina is termed *hematocolpos.* If the fluid extends into the uterine cavity, it is called *hematocolpometra,* and if the cavity of the Fallopian tubes is involved, the term *hematocolpometrosalpinx* is applied. If the accumulation is of a serous, suppurative, or gaseous nature, the condition is known respectively as hydrocolpos, pyocolpos, or physocolpos. The treatment of the accumulation of menstrual fluid within the genital canal as a result of stenosis of the vagina or an imperforate hymen consists of free incision of the membrane covering the orifice, removing the accumulated fluid, irrigating the cavity with warm salt solution, and packing with iodoform gauze. If the edges of the incision show a disposition to adhere, they should be separated by the introduction of graduated vaginal plugs.

Complete absence of the vagina is uncommon, and is usually associated with an absence of the uterus and Fallopian tubes, and occasionally of the ovaries, though the absence of the vagina is not always associated with an absence of the latter organs. This condition, like stenosis of the vaginal canal, may not be recognized until puberty. The treatment of absence of the vagina depends upon the desires of the individual. If the woman contemplates matrimony, a new vagina may be made. It consists in making an incision in the vulva between the urethra and rectum. With a sound in the bladder

and the finger of an assistant in the rectum the tissues between these structures are separated by blunt dissection until the peritoneum is reached, which may or may not be incised. The cavity is made as large as possible, and flaps from the labia minora and majora, if present, are then dissected up and turned in to form a lining membrane for the new canal. If these structures do not afford enough tissue to line the new vagina, flaps may be dissected from the inner sides of the thighs, and made to form a lining membrane for the newly created canal. These flaps should be anchored within the vaginal canal by sutures, and the tendency to cicatricial contraction should be overcome by the repeated introduction of glass plugs. Carl Beck has constructed an artificial vagina by first making a transverse incision immediately over the symphysis pubis, as in the operation of transverse suprapubic cystotomy. He then dissects downward between the peritoneum and the bladder, hugging the bladder closely to the rectovesical space. A counteropening through the tissue between the rectum and urethra by blunt dissection is made continuous with the suprapubic opening. By this method a channel is established, extending from the perineum to above the pubes, but without opening the peritoneal cavity. Two skin-flaps are then dissected from the inner side of the thighs, their bases being represented by the labia and their length being sufficient to extend through the depth of the newly formed canal. These flaps are grasped with forceps introduced from above, drawn through the canal, and sutured to its upper end. The suprapubic opening is then closed, and the newly established channel is packed with iodoform gauze, so as to press the flaps laterally against the sides of the passage. Baldwin, realizing the advantage of a mucous membrane lining over skin, advocates the use of a loop of a lower portion of the ileum or sigmoid flexure. He would incise the tissue of the perineum and then dissect upward between the rectum and urethra, open the abdomen, and grasp the central portion of the sigmoid with forceps, introduced from below, and draw the bowel downward through the new canal to the perineum. This part of the bowel should then be detached, being careful not to injure the vessels of the mesocolon. The continuity of the bowel should then be restored by an anastomosis. One end of the vaginal loop should be inverted and closed with a purse-string suture, while the other end should be attached around the cervix with interrupted sutures. The abdomen should then be closed, and the vaginal loop opened, packed with iodoform gauze, and the edges sutured to the skin. This procedure would form a double vagina, but later the septum between the two canals may be removed by clamp pressure. Mackenrodt advises the employment of vaginal mucous membrane removed from patients operated upon for prolapsus as tissue lining for newly formed vaginæ.

Occasionally, in irregular development of the vagina, the partition of Müller's ducts fails to disappear, and a double vagina may be present, with a septum or partition extending from the uterus to the

vaginal orifice. In this condition the one side of the vagina may appear as a small tubular canal, while the opposite side may be well developed, or two well-developed vaginæ may be present. This condition should be treated by the removal of the septum, the stumps of the septum being quilted with a continuous catgut suture or cauterized by the thermocautery. The walls should then be kept from adhering by the introduction of iodoform gauze or vaginal plugs. In irregular development one tube may develop to normal size, while the opposite tube may be present as a small fibrous cord.

Malformations of the Uterus.—The uterus may be absent, but this condition is extremely rare. When it exists, it is associated with an absence of the other organs of the genital canal, and occa-

Fig. 113.—One Half of a Bilobulated Uterus Containing a Three Months' Fetus (Montgomery).

sionally of the ovaries. Absence of the uterus, however, is not necessarily associated with absence of the ovaries, and this is due to the fact that the ducts of Müller have an independent origin, and are not derived from the mesonephric duct. The uterus may be present as a rudimentary body, and appear as a small fibrous thickening on the posterior wall of the bladder. It may also be represented as two vertical fibrous ridges, or appear as an infantile structure. This is an organ that retains its fetal shape for several years after birth. A uterus of this type may never continue to full development, and, therefore, it is a functionless structure. It is characterized by a decrease of all its dimensions and by a greater development of the cervix than the body, the former portion forming two-thirds and the

latter one-third, a complete reversal of the normal condition. The uterus may be divided by a septum, due to a failure of the partition formed by the coalescence of Müller's ducts to disappear. This septum may be limited to the upper part of the uterus, or it may

Fig. 114.— ervices of Double Uterus (J. M. Fisher).

extend to the internal os, or even to the external os, dividing the organ into two cavities. The two sides may be equal or unequal, one side being well developed and the other side being small and poorly developed. This septate condition is the most frequent form of

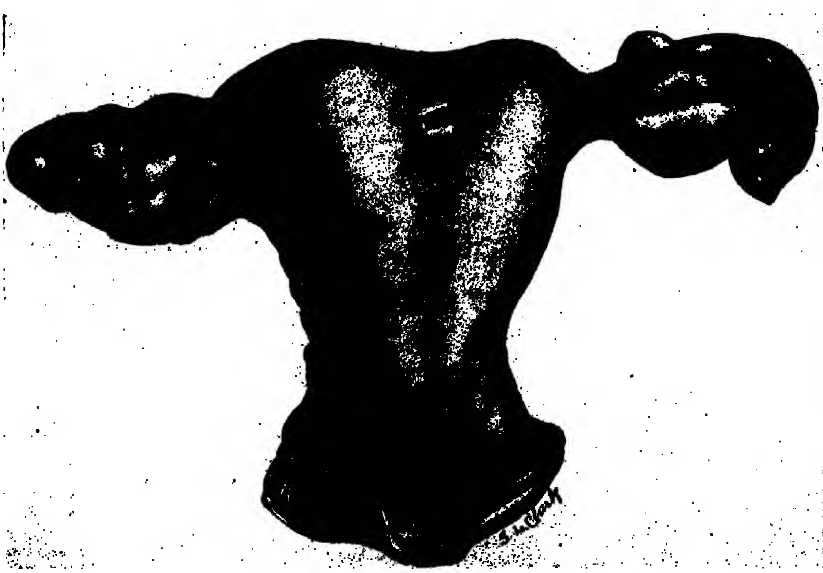

Fig. 115.—External Surface of Double Uterus (J. M. Fisher).

malformation of the uterus. The organ may appear as two distinct lobes attached to a single cervix, known as uterus bilobularis (Fig. 113). Fig. 113 shows one half of a bilobulated uterus containing a three months' fetus. The organ of the opposite side

in this patient was normal in size and was allowed to remain. The tubes and ovaries were normal. This patient was operated upon for an inevitable abortion, and the diagnosis of the unusual condition was not made until the time of operation. The uterus may also appear as two cornua attached to a single cervix, when it is termed uterus bicornis bicolis. When two separate and distinct organs exist, each with one tube and ovary, the deformity is termed uterus didelphys (Figs. 114–116). The two canals of Müller may be unequally developed, and thus produce inequality of the two sides of varying form. The canal of one side may be completely atrophied, while the other presents a well-developed horn—the uterus unicornis. Usually total absence of one side is associated with an absence of the corresponding tube, and occasionally of the ovary. In the con-

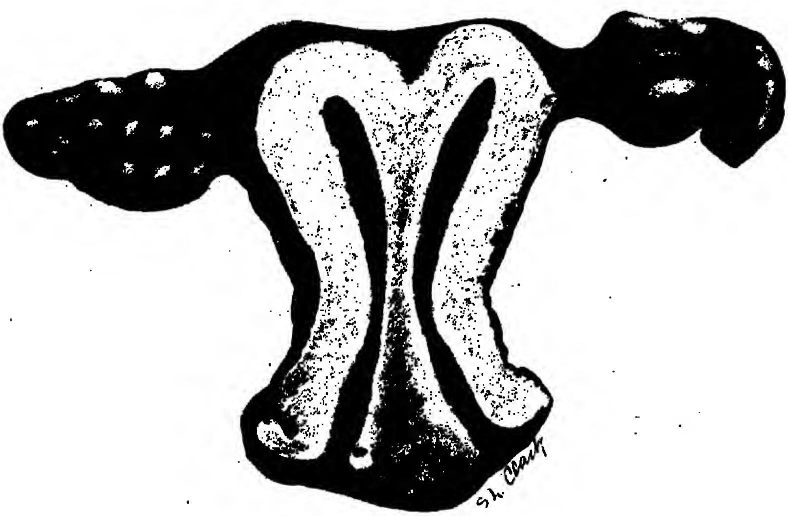

FIG. 116.—INTERIOR OF DOUBLE UTERUS (J. M. Fisher). Vertical section of Figs. 114 and 115.

dition known as uterus unicornis, only one duct develops. This structure may be rudimentary, or it may appear as an organ well developed and capable of fulfilling its designed function, as shown in Fig. 117. In this patient the organ occupied the right side of the pelvis, and was provided with a normal Fallopian tube. The ovary was situated in the posterior leaflet of the broad ligament. Müller's duct of the left side was totally absent, but the left ovary was present, and was anchored to the peritoneum over the sacro-iliac joint. This patient gave birth to a normal child twenty-one years before the operation.

If the organs are rudimentarily developed and pregnancy takes place, the condition should be regarded with the same degree of gravity as pregnancy occurring in a Fallopian tube, and if recognized,

the same treatment should be instituted. Atresia may occur in the canal of a rudimentary or poorly developed horn, and may lead to an accumulation of menstrual secretion and the formation of a tumor of varying size. The diagnosis of such a condition would perhaps be largely accidental.

Accessory uteri have been reported, and Hollander, according to Montgomery, found a second uterus lying in front of the normal organ, between it and the bladder. It consisted of a cervix with two orifices, but was not provided with adnexa or round ligaments.

Absence of the Fallopian tube is a rare occurrence, and is associated with a similar condition of the remaining portion of the genital canal. The ovaries, however, may or may not be absent. The absence of one tube is of a more frequent occurrence, and is usually

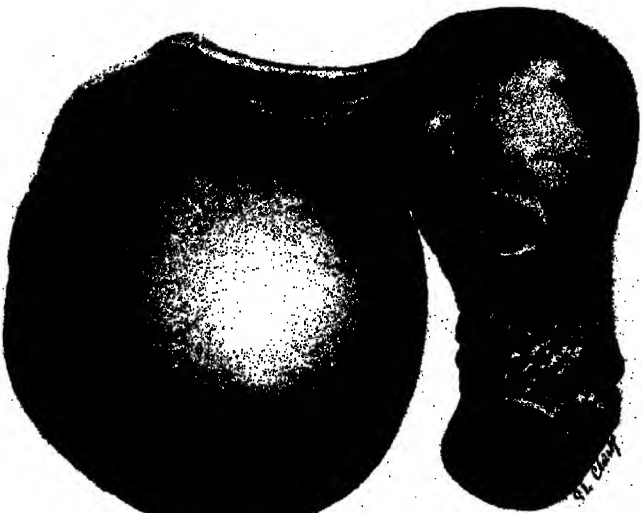

FIG. 117.—AN UNUSUALLY WELL-DEVELOPED UNICORNATE UTERUS COMPLICATED BY AN OVARIAN CYST (Montgomery).

associated with a unicornate uterus. The tubes may exist as rudimentary structures, appearing as small fibrous cords, and this is frequently caused by an attack of fetal peritonitis. It is not uncommon to find Fallopian tubes containing accessory ostia or openings. These are located on the surface of the organs and near the fimbriated end. Occasionally the tubes are not provided with canals, while, on the other hand, two canals, one below the other, may be present. Accessory tubes have also been described. Displacements and distortions of the tube from congenital causes are not uncommon; these lesions have been described as causes of tubal pregnancy.

Absence of the ovaries is an exceedingly rare condition. It is the least frequent malformation of the female genitals. Absence of the ovary of one side is usually associated with absence of the cor-

responding kidney, and occasionally some malformation of the genital canal may be associated, but absence of the ovaries may exist without any derangement in the genital canal.

Rudimentary ovaries are not very frequent, but more frequent, of course, than an absence of these structures. In rudimentary organs the Graafian follicles are poorly developed or wholly absent, menstruation is scanty or may not occur, and the woman is, as a rule, sterile. Supernumerary ovaries are exceedingly rare; only one authentic case has been recorded. Accessory ovaries have been frequently found in relation with a normal ovary, and usually enveloped by the same covering. This condition is due to a constricting-off process during development. Accessory ovaries have been assigned as the cause of the continuance of menstruation after bilateral oöphorectomy, but it is a question whether the persistence of the menstrual flow after operation is not due to failure to remove all portions of the diseased organs, and not to accessory structures.

Congenital displacements of the ovaries are not infrequent. They have been found in various positions in the abdomen and pelvis, and cases are frequently recorded where ovaries have formed part of the contents of a hernial sac.

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SURGERY OF THE VULVA AND VAGINA.

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General Considerations.—Before considering the surgical diseases of the vulva and vagina individually, it is well to recall some of the anatomic peculiarities of the parts and their relation to pathologic lesions in general.

1. The loose tegumentary and fibrolipomatous character of the mons and labia indicates the hypertrophies and the forms of new-growths occasionally met with in this region, while the open-mouthed follicles of both the larger and lesser labia, together with other glandular structures, present ready avenues for infection that frequently terminate in suppurative or ulcerative processes.

2. The irregular contractile property of the tissues of the vulva, depending upon the sparsely though widely distributed non-striated muscular fibers, frequently accounts for the extensive loss of substance in inflammatory and ulcerative conditions, as well as the difficulties experienced in securing cicatrization.

3. The relation of the vaginal bulbs to the erectile system, their free anastomosis with the vaginal and vesical plexuses and with the rich venous supply of the parts, generally not only explain the formation of labial hematoma resulting from external violence or following the traumatisms of childbirth, but likewise account for the alarming hemorrhages that may follow the rupture of a varicose vein or a wound of the deeper parts, either by accident or during an operation.

4. The abundant nerve-supply, both spinal and sympathetic, of the external parts accounts for the intense itching, hyperesthesia, pain, reflex phenomena, and constitutional disturbances that frequently attend apparently insignificant local lesions.

5. In the differentiation of the more frequent forms of labial enlargements the situation, under normal conditions, of Broca's sac,[1] its relation with the inguinal canal, and the danger of mistaking a labial hernia for some other form of enlargement, should be constantly borne in mind.

6. Nothing in the study of malignant disease of the vulva or vagina is of greater clinical importance than a knowledge of its lymphatic extension and glandular involvement. For a detailed description of the lymphatics, so essential to a proper understanding of the subject, the reader is referred to treatises on anatomy.

7. The superimposed layers of squamous epithelium and the resemblance of the vaginal mucous membrane to the skin in all but the presence of a horny layer and of glandular elements in a large measure account for the comparative immunity of this structure to infectious processes, and the readiness with which it throws them off when once established; while the loose connective tissue forming the deeper structure of the vagina, with its valveless venous plexus and large lymphatic sinuses, explains the embolic processes, together with the phlegmonous and wide-spread destructive changes that may attend the rarer and more penetrating forms of inflammatory disease, as well as the extraordinary malignancy and utter hopelessness of cancer of this portion of the body.

SURGERY OF THE VULVA.

INFLAMMATORY AND ALLIED DISEASES OF THE VULVA.

Vulvitis.—Bacteria are practically the exciting agents of all varieties of vulvitis. The vulva is constantly exposed to their invasion, but their deleterious influence usually is resisted by the stratified

[1] The elastic tissue of each labium is so arranged as to form a sac having its neck at the external inguinal ring and its fundus just above the posterior commissure. It is filled with loose connective tissue and fat, and is rarely well defined, save in cases of labial hernia. It was first described by Broca.

epithelium of the vulvar structures, while the normal acid discharge from the vagina, with its immunizing flora, is largely inimical to the growth of pathogenic germs generally. Among the structures of the vulva with diminished resistance to bacterial invasion, in which infection is more persistent and most destructive, are the sebaceous glands and the hair-follicles of the labia, the vestibular glands, Skene's ducts, and the vulvovaginal glands, or glands of Bartholin. Indeed, it is doubtful whether the last-mentioned structure, when once invaded by the gonococcus, is ever completely freed from the infection. In children, the tender epithelial covering of the labia and the scanty vaginal secretion offer a lowered resistance to invading micro-organisms; as a result, vulvitis is more frequent before puberty, has a greater tendency to involve the surrounding structures, and may become a much more serious condition than in the adult. The relative immunity afforded by the protective forces mentioned may be lowered by several conditions, designated as predisposing or contributing causes of vulvar inflammations. Of these, uncleanliness is the most prominent. If the collected secretions from the sebaceous and sweat-glands, together with the discharges from the uterus and vagina, are permitted to accumulate, they may undergo decomposition, macerate, and irritate the parts with which they come in contact. Acrid discharges from urinary or fecal fistulas, malignant disease, or necrotic tumors of the uterus invariably produce vulvitis. Persistent scratching of the vulva to allay itching from any cause, masturbation, and too frequent coition may injure the delicate vulvar tissues, with resulting inflammation.

Streptococcic infection of vulvar lacerations excites a form of vulvitis known as diphtheric, because of the presence of a fibrinous exudate or pseudomembrane resembling a diphtheric condition, but in which the Klebs-Loeffler bacillus is absent. True diphtheric vulvitis is possible, but rare, and usually occurs in childhood.

Symptoms.—The early symptoms of all varieties of vulvitis are itching of the part, a sense of discomfort, especially on walking, increased discharge, burning pain, aggravated by exertion and contact of the urine with the inflamed surface. The changes which occur in the vulvar tissues depend largely upon the degree of irritation and the infecting organism. In the milder or catarrhal form induced by uncleanliness, irritating discharges, pediculi, etc., the labia become swollen, tender, hyperemic, and bathed in mucus or mucopus. The inflammation may be limited to the vulva, extend outward over the buttocks or upward into the vagina, and may involve the deeper pelvic structures. When the sebaceous glands and hair-follicles are involved, they project as reddened papules or pustules, producing a form known as follicular vulvitis.

Gonorrheal vulvitis is characterized by a greater intensity of the symptoms, more swelling of the parts, a distinct purulent, yellowish discharge, by a tendency to involve the urethra, the vulvovaginal and inguinal glands, and to extend upward into the vagina and the

cervical canal. As a result of the urethral involvement, frequent and scalding urination is so common that it is almost considered diagnostic of a gonococcic infection. Pressure along the course of the urethra usually causes the extrusion of pus through the external meatus. Bartholin's glands become swollen and tender, and pressure upon them likewise results in the appearance of a drop of pus at the mouth of the duct. The inguinal glands are swollen, tender, and frequently suppurate.

In *puerperal vulvitis*, chills, fever, sweats, and other constitutional symptoms are more common than in the other varieties; local symptoms are usually aggravated; existing vulvar lesions are covered with a yellowish or brownish exudate, and surrounded by an edematous and tender zone.

Chronic vulvitis usually results from the untreated catarrhal or exanthematous varieties. The most common symptom is pruritus. (See Pruritus Vulvæ.) The surface of the labia majora is thickened, fissured, and excoriated.

Treatment.—The treatment of vulvitis consists, first, in the removal of the cause when possible; second, the maintenance of cleanliness, and third, the application of soothing and specific agents.

In the early stage of the catarrhal form rest in bed, with the application of gauze saturated with lead-water and laudanum or a solution of aluminum acetate, allays the inflammation and relieves the itching and burning. Cleanliness is secured by warm sitz-baths and by vulvar irrigations with one of the following solutions: sodium chlorid, 1 dram to 1 pint; boric acid, saturated solution; or bichlorid of mercury, 1:5000.

After the subsidence of the acute symptoms, the application of soothing antiseptic drying powders is indicated, such as bismuth subnitrate and boric acid, or equal parts of zinc oxid and boric acid. If the pruritus is annoying, 2 to 5 per cent. of phenol may be added to these powders. If profuse, the secretion may be controlled by incorporating alum, lead acetate, or tannic acid, to the extent of 25 per cent. Ointments are sometimes more soothing and efficacious than powders. Those which have proved useful consist of 10 per cent. acetanilid, 10 per cent. boric acid, 3 per cent. phenol; or one containing starch, 1 dram, zinc oxid, 1 dram, and benzoinated lard, 6 drams. In vulvitis occurring as an extension of vaginitis, vaginal douches and medicated tampons are a necessary part of the treatment. (See Vaginitis.)

The *treatment of gonorrheal vulvitis* consists in cleansing the vulva with warm solutions of bichlorid of mercury 1:5000, or potassium permanganate 1:2000, and the application, by means of a cotton swab, of solutions of argyrol, 25 per cent., protargol, 2 to 5 per cent., or mercurol, 2 per cent. The vulvar lips should be kept apart with pledgets of sterile gauze. Unless the vagina is involved, vaginal douches should be prohibited. The best results in the treatment of chronic gonorrheal vulvitis are obtained by the employment of

stimulating applications, such as diachylon ointment or citrine ointment, 25 per cent.; or one composed of phenol and menthol, 20 grains of each, camphor, 30 grains, and benzoinated lard, 1 ounce. It is especially in the chronic form that any underlying constitutional dyscrasia, as diabetes, gout, or rheumatism, should be looked for.

Bartholinitis, or inflammation of the vulvovaginal glands, almost invariably is due to infection by the gonococcus, and occurs as an extension of gonorrheal vulvitis. Occasional causes are trauma and infected discharges from the uterus. The infection may involve the duct alone, without extending into the glandular substance itself. The ostium becomes swollen, reddened, and prominent, and pressure upon the duct causes the appearance of a drop of thick yellow pus. The symptoms are those of the accompanying vulvitis.

The infection may persist in the duct after it has disappeared from the other vulvar tissues, and subsequently, as the result of coition or other irritation, reproduce vulvar inflammation. When the deeper structure of the gland is involved, it usually results in the formation of an abscess. This may occur either during or subsequent to the acute stage of vulvovaginitis. The abscess appears as an ovoid swelling in the posterior part of the labium. The surface of the tumefaction is somewhat glistening, hyperemic, and occasionally bluish, especially over the area where pus has formed. It is of doughy consistence, and fluctuates when it has undergone suppuration.

Symptoms.—The symptoms are burning or throbbing pain in the vulva, aggravated by standing or walking, and relieved, if at all, only when the patient is recumbent. There may be a discharge of greenish, foul pus through the duct, but frequently this is occluded. It rarely undergoes spontaneous recovery, and even after apparent cure of abscess formations by incision and evacuation, recurrences are common.

Treatment.—In the early stage, before suppuration, the treatment consists of rest in bed and the application of hot poultices for the relief of pain, which, if severe, should be relieved by moderate doses of morphin. Plass reports 21 cases, in which 14 patients were successfully treated according to Bier's hyperemia method, by a specially constructed apparatus, the entering tube of which is prolonged within the glass, so that the rubber tubing and ball cannot be infected with the discharge. The glass is so placed that the outlet of the inflamed gland lies within the opening. It is applied for thirty minutes with the patient in bed in two sittings each day. The pain is relieved, the infiltration disappears, and the secretion soon becomes normal.

After an abscess has formed, it should be freely incised upon the inner aspect of the labium, the pus cavity thoroughly evacuated, swabbed with pure phenol, and drained with iodoform gauze. The gauze drain should be changed daily as long as pus is present. To avoid the possibility of a recurrence, the gland should be completely extirpated after the subsidence of the acute symptoms.

Extirpation is accomplished by incision of the overlying structures, extending the entire length of the swelling. The bulging glandular

tissue, unless it is cystic, is grasped with forceps and removed from the surrounding structures either by blunt dissection, which is preferable, or by cutting around it with scissors or scalpel. Hemorrhage, if profuse, should be controlled by ligating the bleeding vessels. Usually, however, the bleeding is controlled by the sutures employed to close the wound. These consist of interrupted sutures of silkworm-gut placed about one-third of an inch apart, and passed deeply so as to obliterate the cavity left by the removal of the gland. Dry dressings are applied and held in place by a T-bandage. The sutures should be removed in about a week.

Cyst of Bartholin's gland may occur from an occulsion of the duct resulting in a retention of the glandular secretion; or, as is frequently the case, precipitation of the solid constituents of a chronic abscess upon the walls of the sac takes place, leaving the watery elements to form the enlargement. The cyst appears as a globular, elastic tumor in the posterior half of the vulva. It may vary in size from that of a hazel-nut to that of a large lemon. Cysts of the duct are usually smaller and more superficial than those of the gland proper.

Symptoms.—The smaller cysts are usually without symptoms. The larger produce a sense of fullness in the vulva and discomfort, especially on walking. Being a source of constant irritation, they may induce inflammation and suppuration.

Diagnosis.—The location of the tumor, its globular form, elasticity, and painlessness will usually determine its nature. It must be differentiated from labial hernia, hematoma, and hydrocele.

Treatment.—Extirpation. To insure its complete removal it is advised first to puncture and empty the cyst cavity, then fill it with melted paraffin, which may be quickly hardened by the application of ice. This is best accomplished by the use of an antitoxin syringe, with a needle having a large bore. The secondary tumor thus formed presents definite outlines and facilitates the removal of the entire sac. The wound should be closed with deep sutures, as recommended in chronic inflammatory conditions of the gland following abscess formations.

Abscess of Skene's Ducts.—The extension of gonorrheal vulvovaginitis to the urethra is so common as to be almost pathognomonic. The urethral inflammation is usually transient. It may persist, however, in Skene's ducts, and result in suppuration. These ducts, the open mouths of which may be seen on the floor of the urethra, one-eighth of an inch from the meatus, extend upward beneath the mucous membrane about three-fourths of an inch. The abscesses thus formed, therefore, are suburethral in character, and project as painful, ovoid, fluctuating tumors in the vestibule of the vagina, on each side of the urinary meatus. Pressure upon them results in the appearance of pus at the urethral orifice. These abscess formations are very rare, only one case of the kind (Fig. 118) having come under my own observation at the gynecologic clinic of the Jefferson Hospital in twenty years.

Treatment.—Evacuation of the abscesses by free incisions and iodoform gauze packing until the cavities have become obliterated.

Lupus of the Vulva.—If the term is to signify demonstrable tuberculous disease, lupus of the vulva and vagina is extremely rare. The discovery of tubercle bacilli is essential to establish an undoubted diagnosis. The process is characterized by ulcerative areas, having grayish, friable granulations and tuberculous nodules undergoing cheesy degeneration, in addition to an increased growth of the connective-tissue elements, with consequent thickening and induration. While the ulcerations indicate active involvement of structure at some points, in others there is an evident tendency toward cicatriza-

FIG. 118.—ABSCESS OF SKENE'S DUCTS.

tion, with apparently healthy intervening tissue. It is generally found in the second and third decades of life.

Symptoms and Prognosis.—The disease is attended by little pain, is essentially chronic in its manifestations, and may continue for years without impairing the patient's general health. The prognosis depends on whether the disease is primary or secondary. If primary, a cure can be effected; if secondary, recurrence is apt to follow its removal. Its localization in the vulva may be the most prominent symptom, while the original focus of the disease remains concealed.

Treatment.—The treatment is the same as tuberculous disease in other portions of the body. An outdoor life, good nutrition, and general tonics are always indicated. Locally, the treatment consists in the thorough removal of the disease by the use of the knife, curet,

or actual cautery. The *x*-ray has been used with apparent success in a few instances.

Pruritus vulvæ is a symptom, not a disease, and is characterized by itching of the vulva. It occurs as a result of an irritation of the sensory nerve-endings in the skin, and frequently depends upon causes difficult of detection, while in no small percentage of cases its etiology remains unsolved, thus accounting for its persistency and intractability. The neuropathic temperament generally is an essential predisposing factor, and in some cases appears to be the originating center. It is not an infrequent complication of melancholia and other forms of insanity, and its presence in young widows and in women whose husbands are absent for a long time tends to prove a purely neurotic basis, resulting from unsatisfied sexual emotions. Dermatologists as well as neurologists admit a pruritus of nervous origin. While the tendency to a morbid, nervous impressibility exists in almost all cases, the usual exciting causes may be classified as constitutional, local, and external.

Among *constitutional* causes are the various diatheses; diabetes, nephritis, icterus, and circulatory disturbances. Some patients suffer from it upon approach of menstruation or at the time of the flow, while others are afflicted only during pregnancy. *Local* causes include all forms of disordered and diseased conditions of the vulva and anus, irritating discharges of every description from the vagina, or rectum and changes due to the menopause or old age. Exceptionally, it undoubtedly depends upon reflex irritation provoked by intestinal disease or some disorder of the internal generative organs. The *external* causes may be thermic, mechanic, or parasitic. Some patients suffer from this symptom in winter and others in summer. Masturbation, undue manipulation of the parts, especially with dirty hands, the presence of pediculi, ascarides, and various forms of vegetable parasites, are the exciting factors in many cases. Kelly suggests the possible presence of some unrecognized organism pululating in the moisture and secretion of the parts as a cause.

Every case of pruritus, irrespective of the supposed cause, demands an examination of the urine, because, of all constitutional disorders, diabetes is the underlying disease in a large proportion of cases.

Symptoms.—The one dominant feature is itching of a portion or of the entire vulva. Beginning as a slight irritation, sooner or later it provokes an irresistible inclination to scratch and rub the affected parts. This in turn causes more pronounced itching, leads to more constant scratching, with consequent abrasions and inflammatory changes that continue to aggravate the original trouble, thus establishing a vicious circle that results in loss of sleep and rest, failing nutrition, and an increasing nervous irritability, which in rare instances terminates in insanity and may even end in suicide. Such pronounced evidences of the infection are not present in all cases, but in accordance with the underlying cause, the symptoms may vary from insignificant and occasional itching to continual torment. The irritation usually

is intermittent in its manifestations, the remissions occurring at intervals of hours or days. It is usually worse at night, during the warm season, and when the patient becomes overheated from any cause.

Treatment.—To ascertain and remove the underlying cause is the first indication. Constitutional conditions and localized diseased processes must be met in accordance with commonly recognized plans of treatment that need not be referred to here.

If supposed to depend upon a discharge from the vagina, the source of this discharge should be sought for, and a test made to prove that its presence is the responsible factor. This may be done by first cleansing the vagina and then holding back the discharge with a sterile tampon, and in proportion to the relief secured will this be determined as a cause of the trouble. This done, proper measures directed toward the correction of the special disorder causing the discharge, or for neutralizing its deleterious influence, should be instituted. When the irritation is of parasitic origin, or depends upon the presence of special micro-organisms, the parts should be shaven, thoroughly scrubbed with soap and water, and then treated with appropriate germicides. Special skin lesions should be treated as elsewhere on the body surface.

For the mere alleviation of the pruritus itself there is hardly a lotion, ointment, or powder supposed to have the property of allaying irritation that has not been tried and found wanting. The application of very hot water often gives decided relief. Washes or ointments containing one or more of the following have been found useful: Carbolic acid, cocain, lead-water and laudanum, boric acid, menthol, alcohol, borax, chloral, camphor, lime-water, ichthyol, guaiacol, nitrate of silver, diachylon ointment, and calomel powders. As the trouble is aggravated by friction, heat, and nervous excitement, these things should, if possible, be avoided. Tea and coffee, stimulants, rich and highly seasoned foods of every description should be interdicted. Proper hygienic conditions with reference to environment, air, bathing, clothing, and exercise often aid the physician in bringing about a cure in an otherwise intractable case. In the general treatment of these cases, the nervous element should not escape attention. In those of a purely neurotic type, *e. g.*, without demonstrable lesion, the skill and tact of the attendant may be taxed to the utmost, and often without result. The *x*-ray might prove of value in some cases.

When local and constitutional measures fail to give relief, one of two plans may be followed surgically: either the parts affected can be excised, or resection of the sensory nerves innervating the structures can be done. Hirst reports three cures by resecting the genital branch of the genitocrural, the ilio-inguinal, the perineal branches of the pudic, the dorsal nerve of the clitoris, and the inferior or long pudendal nerve on both sides. To do this requires four incisions: Two corresponding with the incisions for the Alexander

operation; two along the inner edges of the ascending rami of the ischia, from the tuberosity to a point two inches above it.

Vaginismus, like pruritus vulvæ, is a symptom and not a disease; the two conditions may be associated. It is characterized by painful tetanic, neuromuscular spasms of either the muscles surrounding the vulvovaginal orifice (vaginismus inferior) or the levator ani muscles (vaginismus superior). It is excited more especially by efforts at coition or upon an attempt to make a vaginal examination.

Etiology and Symptoms.—In most cases it is a distinct neurosis occurring in young, nervous, hysteric brides, but may develop in women who have borne children. In some cases it is secondary to irritating or painful diseased conditions of any portion of the genital system, pelvic peritoneum, bladder, urethra, or rectum. Among the most frequent local causes are fleshy, unyielding or inflamed hymen, irritable carunculæ myrtiformes, fissures and abrasions of the introitus, neuroma of the fossa navicularis, urethral caruncle, and anal fissure. On the part of the male, an unusually large penis or ill-directed efforts at coitus, impotence, or premature ejaculation may induce extreme nervous irritability and localized sensitiveness in the wife, with resulting vaginismus.

The spasmodic and painful manifestations incident to the muscular contractions usually render intercourse impossible. If the hypersensitive area involves the vulvar structures, painful spasms of the vulvovaginal orifice may be excited by the slightest touch, and attempts at coition may be attended with tetanic seizures of the muscles of the thighs and convulsive movements of the entire body. If the levator ani is at fault, no difficulty may be encountered at the vaginal entrance, but upon partial penetration a resisting contraction is met with, and if the spasm for the moment is overcome and the head of the penis passes the edge of the levator, the corona of the organ may be encircled by the muscle, resulting in temporary vaginal imprisonment (penis captivus), with excruciating suffering to both participants. Women suffering from persistent vaginismus usually are very nervous and irritable, and sooner or later fail in general health.

Prognosis.—This is unfavorable as to cure if nothing is done. Sterility is common. If successful coitus on the part of the male is at all possible, one or two repetitions of the act may overcome the difficulty. Pregnancy and its normal termination usually effects a cure. Removal of the localized causes likewise relieves the condition, but not in all cases.

Treatment.—Interdict attempts at coition until a cure has been effected, unless convinced of the possible consummation of the act and of its therapeutic value. The patient should occupy a room and bed alone. Insist upon making a thorough pelvic examination, if necessary under anesthesia, and thus ascertain, if possible, the underlying cause. Whatever the structural lesion (with few exceptions) may be, even if its eradication is not to be attempted at the time,

but more especially if no appreciable local cause is discovered, advantage should be taken of the patient's anesthetic state forcibly to overstretch the vagina with the fingers to the extent of feeling some of the sphincter fibers give way. This in itself may afford considerable relief, and will effect a cure in not a few of the simpler forms of the trouble.

Whatever else may be necessary, the patient's general health should not be neglected. A proper hygienic regimen concerning hours of rest and sleep, exercise, bathing, and attention to the digestive and eliminative organs are essential to secure the best results.

The cases depending upon gross pelvic lesions usually are the easiest cured. The removal of the disease generally relieves the

FIG. 119.—V-SHAPED INCISION THROUGH LEVATOR ANI MUSCLES AND PERINEUM FOR VAGINISMUS (Sims).

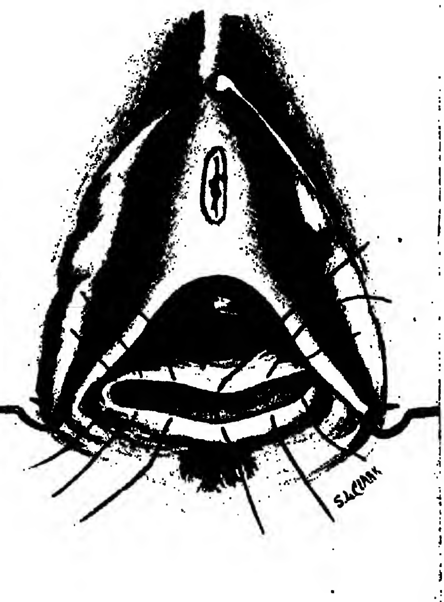

FIG. 120.—INCISION DRAWN OUT (Hirst). Sutures introduced.

condition, excepting in those with an established, localized, hypersensitive habit, and these finally yield to appropriate local and constitutional measures. If abnormalities of the hymen or caruncles are the causative factors, they should be treated or removed as may be indicated. Fissures of the introitus or the anus should be treated by divulsion and applications of nitrate of silver. Neuromata of the fossa navicularis and urethral caruncles require thorough removal, and all other local abnormalities should be met in accordance with well-known principles of surgery.

The severe cases without a demonstrable cause are, as a rule, the most intractable to treatment. In mild cases of a neurotic type a

pledget of cotton saturated with a 5 per cent. solution of cocain and placed into the vaginal orifice about ten minutes, followed by some unguent, usually permits intercourse without exciting spasm and pain. In 1887 I reported a case of an aggravated character completely relieved by the vaginal application of galvanism. In some of the severer forms of the affection a cure is effected by forcible dilatation under ether, as already indicated, followed by the introduction of a snugly fitting glass plug, to be worn from three to four hours daily, extending over a period of several weeks or months. In obstinate and otherwise intractable cases with no palpable cause, Sims recommended excision of the hymen, forcible stretching of the vaginal orifice, followed by V-shaped incisions, extending deeply into both vaginal sulci, two inches in length, and half-way through the perineum. Bougies as large as could be tolerated were then introduced and worn from two to four hours daily, extending over a period of two or three weeks. Hirst makes practically the same incisions (Fig. 119), and then introduces a transverse row of sutures from above downward, uniting the vaginal mucous membrane to the skin of the perineum (Fig. 120). He thus secures a dilatable vulvar orifice and introitus, with a lessened degree of the contractile power of the levator ani, and in this way claims to have cured some of the worst cases. Tavel resects the internal pudic nerve. This is reached on each side by an anteroposterior incision in the corresponding ischiorectal fossa, midway between the tuberosity of the ischium and the outer margin of the anus. The nerve is located by the pulsation of the accompanying artery and divided. The peripheral portion is then twisted off.

Kraurosis vulvæ was first described by Briesky in 1885. It is a rare disease.

Pathology and Etiology.—A specific form of progressive atrophy and contraction of the vulva. The vestibule presents depressed, irregular, reddish-brown spots that disappear as the disease progresses. The labia and clitoris become pale, shrunken, wrinkled, and as distinct formations may become completely obliterated. In the later stages of the disease the sebaceous and sudoriferous glands, the hair-follicles, and likewise the blood-vessels disappear, the parts become whitish, striated, brittle, and present the appearance of irregular cicatrices. The vulvovaginal orifice becomes narrowed and inelastic. Longyear has observed sclerosis of the loose cellular tissue of the parts as the essential lesion, which, by its contraction, obliterates the nutrient vessels, thus causing the characteristic shrinkage of the overlying structures. The cause of the disease is unknown. It is found in virgins and married women, in adult life and old age. In some cases it has followed removal of the ovaries. It predisposes to cancer.

Symptoms.—Some of these patients suffer little or no inconvenience until late in the progress of the disease. Burning pain, intense pruritus, and dyspareunia are among the most prominent symptoms. A

disagreeable tension of the skin in walking and smarting pain on urination are likewise complained of. The hyperesthesia and pruritus, with loss of sleep and consequent anorexia, sooner or later affect the patient constitutionally.

Treatment.—The complete removal of the sclerosed cellular tissue, together with the contracted overlying structures, is the only treatment that offers any hope of cure or relief from the distressing symptoms. The stenosis is incurable. As a soothing application, and especially for protecting the parts during urination, an application of carbolized mutton-suet is of some value.

Hypertrophies and Benign New-growths of the Vulva.

Simple hypertrophy of the vulva, sufficient to be considered abnormal, rarely involves all the vulvar structures. The parts most frequently affected are the labia minora and the clitoris.

Hypertrophy of the labia minora may involve one or both labia to a degree that they may extend down and unite in front of or behind the anus, and in some cases project like wings or aprons covering the vestibule and the clitoris. It is not an infrequent abnormality among Hottentots, in whom the hypertrophied labia may reach to the knees.

Irritation from friction, frequently resulting in inflammatory changes, is the principal symptom.

Treatment.—Amputation of the labia.

Hypertrophy of the clitoris may occur, so that the organ attains the size of a boy's penis. The condition in some cases leads to onanism from friction, interferes with coitus, or gives an abnormal direction to the stream of urine.

Treatment.—Partial or complete amputation of the organ is the only remedy, but should not be advised unless the condition causes symptoms.

Clitoridectomy, or excision of the clitoris, may not only be demanded in cases of hypertrophy, but for the cure of malignant or tuberculous disease, or for the relief of extreme hyperesthesia of the organ. A circular incision is made around the exposed portion of the organ; the prepuce is then slit close to the symphysis; the clitoris is now dissected out of the surrounding tissues, and severed close to its origin from the crura. Hemorrhage is controlled by ligatures, and the wound is closed by deep and superficial sutures, as may be indicated.

Hypertrophy of the prepuce of the clitoris and *adhesions of the prepuce and glans* are abnormalities that frequently cause very annoying symptoms. The irritation of the former may lead to masturbation, while the latter, owing to the irritation of the glans by decomposing smegma, may cause serious neurotic disturbances.

Treatment.—Amputation of the redundant skin, with suture of the wound in the one, and breaking up the adhesions and keeping the surfaces apart until the parts have healed in the other, are the indications.

Elephantiasis of the vulva is characterized by hypertrophy of the skin and subjacent connective tissue, associated with dilatation of the lymph-channels. It should not be confounded with the elephantiasis of the tropics, which is of parasitic origin and usually affects the lower extremities. The non-parasitic variety may be met with in any climate. It may be of rapid or slow growth, covering from one to thirty years. The clitoris, labia minora, labia majora, and perineum are the principal points of origin of the disease. The resulting tumor may involve the whole or part of the vulva, may attain a size to reach below the knees, and weigh thirty or more pounds. The surface of the growth may be smooth, rough, warty, or ulcerated, and is frequently fissured and lobulated. Negresses are very much more susceptible to the disease than white women.

The **etiology** of the disease is unknown, but it is generally conceded that syphilis is the most frequent cause. An obstruction to the lymph-channels appears to be an essential factor in its development, depending in some cases upon chronic inflammatory changes.

Symptoms.—Itching, dull aching pain, and ulceration are among the most prominent symptoms, and, in accordance with its size, the tumor may cause difficulty in walking, urination, defacation, and copulation. The disease in itself does not impair the patient's general health, but the mechanic difficulties that may ensue and the abrasions and ulcerations from friction that usually attend these growths may lead the patient to adopt a secluded and sedentary habit, with all its evil consequences.

Diagnosis.—It is differentiated from other growths of the vulva by its being a simple hyperplasia and hypertrophy of apparently normal skin and connective tissue, without lines of demarcation. In the presence of doubtful ulcerations a section of the tissue should be examined microscopically.

Treatment.—This consists in the removal of the hypertrophied structures. In some cases it may be necessary to place the patient on a preliminary course of antisyphilitic remedies, or to treat the diseased parts with antiseptic washes and douches for several days before operation.

The operations should be done under the strictest aseptic and antiseptic precautions, in order to avoid infection and its ready dissemination through the dilated lymph-channels. Before using the knife all ulcerated surfaces should be thoroughly seared with the thermocautery. By enveloping the mass with gauze, a firm hold may be secured for fixation and traction, while the tissues about the base are incised from above downward, leaving enough skin to cover the resulting wound. A portion of the involved skin may be retained for forming flaps without incurring the risk of a recurrence of the disease. Time will be saved by excising the whole mass at once, controlling the bleeding with hemostats, and subsequently ligating the clamped vessels, and then closing the wound with deep sutures. In the removal of very large tumors Kelly recommends pulling out the

mass to form a pedicle, transfixing a portion of the base with two or three stout silk sutures, one below the other, severing the corresponding portion of the pedicle overlying the sutures, then tying the sutures. This is followed by a succession of similar steps until the whole tumor has been removed and the wound closed, with but little hemorrhage. (See also Vol. II, p. 595.)

Condylomata of the Vulva.—These warty hypertrophies may be non-specific, gonorrheal, or syphilitic.

Non-specific condylomata occur in two forms: (1) *Hard papillomata* (ordinary warts) may appear singly or be widely separated by healthy skin, as on other portions of the body surface. They are not caused by infection, neither do they infect the parts with which they come in contact. (2) *Pointed warty growths* of a less resisting character than the preceding type, occurring singly or grouped in conglomerate masses, usually pedunculated, may develop as a result of the nutritive stimulus incident to gestation, or may spring from an irritative base, superinduced by mere uncleanliness, while in some cases no assignable cause for their appearance can be detected. They may be autoinoculable.

Gonorrheal condylomata, or condylomata acuminata, pointed condylomata (venereal warts), develop upon an inflammatory base of gonorrheal origin in any portion of the vulva, and rarely in the vagina. The papillomatous outgrowths are branched and pointed; they occur singly, in groups, or as confluent, cauliflower masses. In color they vary from a grayish-white to bright red. Ulcerations are rare unless the outgrowths are exposed to friction or other forms of direct irritation. The surface is usually soft and moist, and may be the seat of a profuse fetid secretion that irritates the surrounding skin. Similar growths upon adjacent skin surfaces produced by contact infection are common. They grow very rapidly during pregnancy, and may disappear after the puerperium. The gonococcus merely is a predisposing factor, and not the essential cause in their development.

Syphilitic condylomata, or condylomata lata, broad condyloma, are merely soft, grayish, exuberant, and exaggerated warty excrescences, with broad bases that might well be termed elevated mucous patches, having the same pathologic characteristics.

Treatment.—*Hard papillomata* (ordinary warts) have no special clinical significance unless they are of large size, exposed to friction, or otherwise unfavorably situated. Excision is the proper treatment.

Non-specific pointed condylomata, as well as those of *gonorrheal origin*, demand, first of all, the removal of the cause by the use of antiseptic douches and cleansing washes. The application of a drying powder, consisting of equal parts of calomel and salicylic acid, with a prolonged daily exposure of the parts to pure air and sunlight, may bring about a cure in the less aggravated forms of the trouble. The application of a saturated solution of iodoform in collodion or a dram of salicylic acid to the ounce of collodion has been found useful in some

cases. Resorcinol, eight parts, combined with one part each of subnitrate of bismuth and boric acid, used as a dusting-powder, is highly recommended by Boeck.

In all cases where the procedure is feasible, especially where the condylomata have attained considerable development, their removal by a clean surgical operation is to be preferred.

Small condylomata, though widely distributed, after cocainization of the parts may be removed with scissors or a sharp curet. A firmly applied compress of aseptic gauze usually is sufficient to control the bloody oozing after the operation. The larger growths demand excision. Owing to the free mobility of the skin in the immediate vicinity of the operation it is possible to remove large areas of the vulvar skin and yet to cover the raw surface with ease, and without undue tension on the sutures.

Urethral Caruncle.—Urethral caruncles are localized inflammatory hypertrophies or angeiomatous growths of the urethral mucosa that usually project from the external urinary meatus, and may, therefore, be considered with the abnormalities of the vulva. They consist of excessively vascularized and hypertrophied papillæ and connective tissue of the mucous membrane of the urethral orifice, forming enlargements of a cherry-red color that vary in size from a millet-seed to a pea or a hazel-nut, are sessile or pedunculated, single or multiple, and may extend around the meatus or up the canal. In accordance with their nerve-supply they are divided into simple and neuromatous caruncles.

Symptoms.—A *simple* urethral caruncle is without nervous elements and is painless. In a *neuromatous* caruncle there coexists an excessive development of nerve-elements, with a corresponding sensitiveness of the part, so that urination, coition, locomotion, and even the slightest touch may cause exquisite pain. As a consequence, the patient may become nervous, hysteric, or greatly depressed. In both types hemorrhage is a frequent symptom. A careless observer may confound the condition with prolapse of the urethra, but the reduplicated cuff-like projection of the mucous membrane is usually easily differentiated from the vascular outgrowth.

Treatment.—Simple, painless angeiomatous caruncles, unless they are of the hemorrhagic variety, require no treatment. Neuromatous and hemorrhagic growths should be excised. The pedunculated growths, if single, may be removed with knife or scissors, after cocainization with an 8 per cent. solution. As a rule, it is best to do the operation under general anesthesia, so that the parts can be fully inspected and a thorough surgical procedure carried out. Unless the growth is completely extirpated, it may recur. A sessile tumor should be lifted up with toothed forceps, and excised well below its base with curved scissors. Excessive bleeding may follow the excision; in closing the wound, therefore, the stitches should be carried well below the raw surface and securely tied.

The operation may be done with a thermocautery. By this means

not only is hemorrhage usually avoided, but the base is cauterized, and this serves as a safeguard against a return of the growth; or the tumor may be destroyed by the use of the electrothermic needle thrust into the depths of the growths at different points. Excision, however, should be the operation of choice. The thermocautery cannot be used without endangering the surrounding tissues, and the electrothermic needle is more or less uncertain in its results.

Lipoma of the Vulva.—Grad found but 29 cases in literature. They have been met with in infancy, and as late as the fifty-first year. These tumors usually present the same characteristics as lipomata elsewhere. They vary in size from that of a bean to a tumor weighing 24 pounds, and may be sessile or pedunculated. The consistency of the tumor varies in accordance with the predominance of fat or fibrous tissue.

Symptoms.—Small growths cause no symptoms. The larger growths may interfere with locomotion and coition, or prove an obstruction to labor.

Treatment.—If pedunculated, the pedicle should be cut and the severed vessels ligated. The wound should then be closed with continuous or interrupted sutures. Sessile growths should be removed by making an incision over the growth through the skin and enucleating the fatty mass, ligating the bleeding vessels, and closing the wound with sutures. It is always best not to remove any of the overlying skin until the growth has been shelled out, in order to avoid a deficiency of skin or undue tension on the sutures after the edges have been approximated.

Fibromyoma of the Vulva.—This is very rare. It usually originates in the labia majora or minora. In some cases it arises from the round ligament, and after a time descends into the labium majus. Fibromyomata of the vulva are of slow growth, round, and well defined, usually of small size, but may attain the dimensions of an adult head. They may be single or multiple, sessile or pedunculated. They are subject to the same accidental and degenerative changes as fibromyomata of the uterus. The skin overlying the tumor is freely movable. As in lipoma of the vulva, the symptoms depend upon the size and situation of the growth.

Treatment.—Excision of the tumor, observing the same precautions as in excisions of lipomata.

The only case of fibromyoma of the vulva that has come under my own observation was the following: Mrs. Y., age thirty-nine, admitted to the Jefferson Hospital April 7, 1909; VI-para; negative family history; pregnant eight and a half months. She first noticed a small tumor in the lower portion of the left labium three years ago. This gradually became larger and took on a more rapid growth after she became pregnant. It was painless, but at times the seat of considerable itching and burning, and, owing to its size, interfered with locomotion.

When I first saw her the tumor was as large as a fetal head, occupy-

ing the lower three-fourths of the vulva. It encroached upon and almost occluded the vulvar orifice (Plate I.). The circulatory disturbances incident to pregnancy were much intensified, and the overlying tissues were edematous, but not adherent. The mass was oblong, smooth, elastic, and freely movable. Operation, April 8, 1909. Ether anesthesia. To limit the loss of blood an assistant grasped the tissues at the base of the mass with both hands, making firm pressure. Through a vertical incision the tumor was enucleated almost exclusively by blunt dissection with the fingers. The resulting hemorrhage from torn venous sinuses though free, was not excessive, and was easily controlled by buried continuous tier sutures of catgut, used for obliterating the deep, excavated-looking wound along the sides of the vagina and rectum. She made an uninterrupted recovery. The growth was of firm consistence, but elastic and edematous. Its

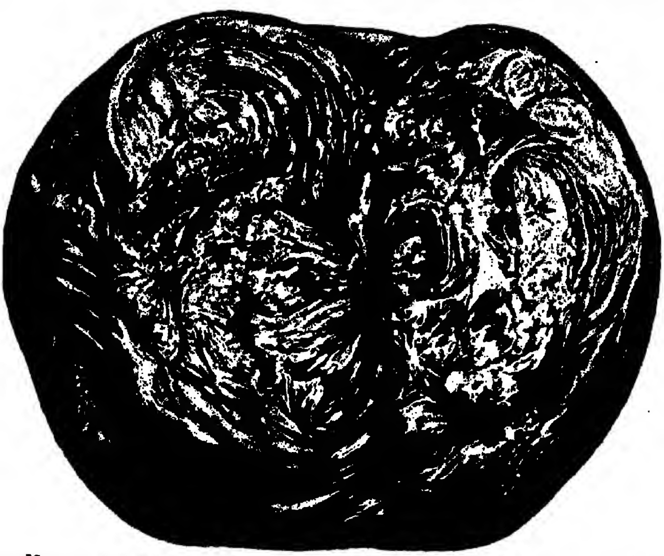

FIG. 121.—MYOMA OF THE VULVA AFTER REMOVAL, SHOWING WHIRLS OF MUSCULAR STRUCTURE.

largest circumference measured twelve inches, and upon section it had a diameter of three and a half by four inches. Dr. A. G. Ellis made a microscopic examination of the growth and found it to be almost a pure myoma (Fig. 121).

Hydrocele.—This is neither a hypertrophy nor a new-growth of the vulva, but is very properly considered in this connection for diagnostic purposes. The same may be said of varicose veins of the vulva.

The terms "hydrocele muliebris" and "hydrocele of the canal of Nuck" have been indiscriminately applied to a variety of cystic enlargements in the inguinal region of the female. Rignoli's classification is the best. Briefly stated, it is as follows:

1. Diffuse hydrocele in the connective tissue surrounding the round ligament.

PLATE I.

EDEMATOUS MYOMA THE SIZE OF A FETAL HEAD IN A PATIENT EIGHT AND A HALF MONTHS PREGNANT (Fisher).

2. Hydrocele of the canal of Nuck, communicating with the abdominal cavity.

3. Encysted hydrocele of the canal of Nuck (without an abdominal communication).

4. Encysted hydrocele of the connective tissue enveloping the round ligament.

Symptoms.—The enlargement usually develops slowly, causing little or no inconvenience unless it attains a large size or becomes inflamed. It is usually globular in form, symmetric in outline, elastic and fluctuating, dull on percussion, and does not disappear on pressure or by posture unless it communicates with the abdominal cavity.

Diagnosis.—In whatever form present, it is generally mistaken for hernia. By recalling the possibility of these cystic conditions and their anatomic and symptomatic peculiarities, the practitioner should rarely fail in making a differential diagnosis in uncomplicated cases. When associated with hernia, which is often the case, the diagnosis becomes more difficult. Careful incision is the safest and most certain diagnostic procedure.

Treatment.—Excision of the sac with closure of the dilated inguinal canal as a prophylactic against hernia. Aspiration followed by irritating injections is unsurgical, and, for obvious reasons, a dangerous procedure.

Varicose Veins of the Vulva.—Varices of the vulva are common, in some cases forming irregular knotty tumors or swellings of large size.

Etiology.—Increased intravenous pressure, depending upon interference with the return circulation, combined with a weakened state of the vessel-walls, are the principal predisposing factors. Pregnancy is the most frequent exciting cause, and if the varicosities antedate gestation, the condition is always aggravated during this period. It may be caused by a great variety of intrapelvic abnormalities, including tumors, uterine displacements, and inflammatory conditions in general. Constipation, prolonged standing, and laborious occupations are responsible for the abnormality in some cases.

Symptoms.—Small varicosities cause little or no inconvenience. The more pronounced forms give rise to a feeling of weight and fullness, dull aching pains, and itching of the parts. The enlargement of the labia may attain a size to interfere with locomotion, with resulting abrasions and ulcerations from friction. The recumbent posture always causes a temporary decrease in the size of the varices, and they may be made to disappear by pressure. Rupture of a vein may occur, causing an open or a concealed hemorrhage (hematoma), or phlebitis may supervene, with a fatal termination.

Treatment.—If the varices are large and troublesome, the patient should be instructed to avoid constriction of the waist, and to support the parts by a compress and a T-bandage. She should be cautioned against heavy lifting and excessive straining at stool. The rupture

of such a vessel may be attended by serious and even fatal hemorrhage, unless the patient makes firm pressure over the site of the bleeding point until professional attention can be secured.

Radical treatment is indicated where palliative measures fail to relieve the symptoms, and consists in excision of the veins. A vertical incision is made through the skin overlying the veins; the varicose mass is now exposed by dry dissection and drawn out so as to form pedicles at its extremities. The pedicles are ligated with catgut; the intervening venous trunks are excised, and the wound is closed.

MALIGNANT NEW-GROWTHS OF THE VULVA.

The vulva appears to be particularly exempt from malignant disease. Schwarz, in 1177 cases of malignant degeneration of the female genitalia, found that 2½ per cent. were primarily located in the vulva, while Gurlt, in 7479 cases, discovered the vulva primarily affected in less than 1 per cent. Even the latter proportion seems too large, and it is more than probable that many of these were secondary, but unrecognized as such.

Carcinoma of the vulva usually occurs at a more advanced age than carcinoma of other parts of the genital tract. It is most frequent between the ages of fifty and sixty years, but has been seen in a woman of thirty-one and as late as eighty-four.

Seat of the Disease.—The most frequent site of origin is the inner side of the right labium minus, below the clitoris. Less frequent points of attack are the sulcus between the labium majus and minus, the anterior and posterior commissures, the clitoris, the urinary meatus, and the vulvovaginal glands. Papillary excrescences at the mucocutaneous junction in old women have a special predisposition to become carcinomatous.

General Description.—Carcinoma of the vulva almost invariably occurs in the form of an epithelioma, although a few cases of adenocarcinoma of the vulvovaginal glands and of Skene's ducts have been reported. The disease usually manifests itself by a superficial infiltration at first, which later develops into one of two distinct forms:

1. A more or less prominent outgrowth, well rounded, nodular or papillary, with a tendency to the formation of epithelial pearls and cornification. It may develop to the size of an ordinary orange, and sooner or later becomes the seat of excoriation and ulcerations that result in the formation of sloughs.

2. The infiltrating or diffuse form, which, owing to the lessened tendency to cornification, is the more active type of the disease. It usually presents an elevated, though flattened surface, with deep infiltration of the tissues and early destruction of the cellular elements, which soon leads to the formation of ulcers, with irregular, indurated edges, covered with coarse, friable, grayish granulations and a foul-smelling discharge. Involvement of the inguinal glands takes place early in the latter form of the disease. Contact infection has been observed.

Extension of the disease usually is at first toward the vagina, but it rarely involves this structure, passing instead up into the groin and down over the perineum.

Symptoms.—Intense itching is the first and most pronounced symptom. Pain is not particularly prominent until the deeper structures become involved, or after the formation of excoriations and ulcerations, when the parts become very sensitive and painful. In doubtful cases the microscope should be used to clear up the diagnosis. The toxemia and cachexia that are sure to follow sooner or later close the scene.

Prognosis and Treatment.—The average duration of the disease without operation is about two years. In no class of cases excepting in carcinoma of the body of the uterus does the radical operation as

FIG. 122.—REMOVAL OF THE CLITORIS, VESTIBULE, LOWER PORTION OF THE URETHRA AND LABIÆ, WITH EXTENSION OF THE WOUND FOR THE REMOVAL OF THE INGUINAL GLANDS.
Sliding skin-flaps from thighs to close wound.

FIG. 123.—WOUND CLOSED.

applied to these parts give such good results when done early in the disease. Schwarz, out of 23 cases, reported 10 recoveries. It is the duty of the physician, therefore, to be particularly alert in making an early diagnosis and in urging prompt surgical interference. Removal of the diseased parts, together with all the remaining vulvar structures and the inguinal glands, is the only treatment. Sloughing tissue should be thoroughly cauterized with a hot iron before beginning the excision. In no case is it possible to say that the inguinal glands are not involved. In performing an operation, therefore, the entire gland-bearing field on both sides should be dissected out first, care being taken to prevent contamination from below. The entire vulva and clitoris, and, if necessary, the lower portion of the urethra, are

removed by an elliptic incision from the upper margin of the mons, uniting with the inguinal incisions to the posterior commissure. The free mobility of the neighboring healthy skin usually permits the closure of large wound surfaces by uniting the edges of the skin to the mucous membrane of the vagina. In very extensive operations it may be necessary to secure sliding skin-flaps from the corresponding thighs (Figs. 122 and 123) to close the defect, and in some cases the dissection may be so extensive that a portion of the wound must be allowed to heal by granulation.

Sarcoma of the vulva is extraordinarily rare, surgeons of large experience never having seen a case. Any one of the various forms of sarcoma is possible. Melanosarcoma is the most frequent. In accordance with the special variety present, the growth may be slow or rapid. Usually it is very rapid, and metastatic deposits through the venous circulation in distant organs are common, and are the ultimate cause of death. Only a few well-authenticated cases of permanent recovery after operation have been found in literature.

Treatment.—The treatment is immediate removal.

SURGERY OF THE VAGINA.

Vaginitis.[1]—Inflammation occurs less often in the vagina than in other parts of the genital tract. Bacteria play the most important role in its causation, and though they are frequently deposited in the vagina and infect the uterus, the vagina itself remains particularly free from their influence. The resistance of the vagina to infecting micro-organisms is accounted for by the stratified squamous epithelium of its lining, the nature of its secretion, which is acid, and by the presence of a normal flora, determined by Döderlein to be antagonistic to morbid bacteria.

The greater frequency of vaginitis in young girls is attributed to the soft, tender, vaginal epithelium, which readily falls a prey to bacterial invasion. The atrophic changes common to the vaginal walls after the menopause predispose to senile vaginitis. Coincident with the increased alkaline discharge from the uterus and cervix during menstruation, pregnancy, and puerperium, the vagina and the entire genital tract are then more liable to infection. Abnormal discharges resulting from uterine disease, necrotic tumors of the uterus, urinary and fecal fistulas have the same effect. The vaginal mucous membrane may be denuded of its epithelium and the character of its discharge altered by foreign bodies, the application of chemic irritants, by the practice of excessive venery, and the use of vaginal douches.

Vaginitis may be either primary or secondary. The primary variety is the less frequent, and usually arises from conditions which injure the vaginal epithelium. The secondary variety appears as

[1] I am indebted to Dr. Alfred Heineberg for valuable suggestions in the preparation of the text on vulvitis and vaginitis.

an extension of disease from the vulva, uterus, or urethra. Either may occur in an acute or chronic form.

The primary variety, because of the nature of its causation, is often essentially chronic from the outset. Vaginitis secondary to vulvar inflammation is usually acute, especially if of gonorrheal origin. When it results from extension of diseases from the uterus or cervix, it is commonly of the chronic type.

Pathology.—The changes found in the vagina depend upon the cause, the severity of the inflammation, and its duration. In the mild, acute form the mucous membrane is reddened, swollen, and covered with a seropurulent discharge. The entire mucous surface may be involved or the disease may appear in isolated patches, separated by areas of healthy tissue. In gonorrheal vaginitis the discharge is more purulent and the hyperemia and swelling more intense. When the inflammation involves the subepithelial tissues, the papillæ of the vagina become infiltrated, project through the epithelial surface, and the mucous membrane assumes a granular appearance, producing what is known as granular vaginitis, which may result in erosions and small ulcerations. Ulceration is common in vaginitis, appearing after the climacteric, and is due to atrophic changes. The contact of such ulcerated areas results in adhesions and the formation of cicatrices. The cicatrization may be so extensive as to obliterate the vaginal canal. Ulceration of a more penetrating nature may result from the pressure of pessaries or the action of strong caustics.

Symptoms.—In acute vaginitis the patient complains of burning pain and a feeling of fullness in the vagina and perineum, aggravated by walking, exertion, and coition. There is a profuse discharge, which, in the milder infections, is thin, milky, and seropurulent, and in gonococcus infection is yellowish, thick, and may be blood-streaked. A complicating urethritis and vulvitis are common in gonorrheal vaginitis. (See Vulvitis.) The symptoms are usually more intense in vaginitis occurring in young girls.

The symptoms of chronic vaginitis resemble those of the acute, differing principally in degree. The vulva frequently becomes irritated by the constant discharge from the vagina, and annoying pruritus results. The discharge in senile vaginitis is thin, serous, and occasionally blood-stained, and is frequently the only evidence of the disease.

Treatment.—In acute vaginitis rest in bed for several days is essential. Constipation should be met with appropriate remedies. The diet should be bland and non-stimulating, avoiding highly seasoned foods, alcohol, tea, and coffee. Local treatment consists in douching the vagina three or four times a day with solutions of boric acid, borax, sodium chlorid, or sodium bicarbonate, one ounce to the gallon. After the subsidence of the acute symptoms, especially in gonorrheal vaginitis, douches of stronger antiseptics, as bichlorid of mercury 1: 5000, or potassium permanganate 1: 2000, are employed

two or three times a day. Every second or third day a cotton-wool tampon saturated with an aqueous solution of argyrol, 25 per cent., or protargol, 2 per cent., or a glycerin solution of ichthyol, 25 per cent., should be introduced into the vagina.

Chronic vaginitis is best treated by daily douches of compound solution of cresol (U. S. P.), 1 per cent., or bichlorid of mercury 1: 2000, and the use of one of the above-mentioned tampons every third day. If this is not effective, the vaginal walls should be cleansed with warm water, thoroughly dried, and painted with a solution of silver nitrate, 30 grains to the ounce, or argyrol, 50 per cent., or compound solution of iodin or formaldehyd, 1 to 2 per cent., and a strip of sterile or iodoform gauze inserted for twenty-four hours to keep the surfaces apart. This treatment should be carried out every four or five days. Good results are sometimes obtained by the use of astringent powders composed of combinations of bismuth subnitrate, zinc oxid, tannic acid, and acetanilid. The patient is placed in the dorsal posture; a Sims speculum is introduced, and the vagina is douched and thoroughly dried. The powder is introduced through the speculum, and held in the vaginal vault with a strip of gauze. Unless senile vaginitis produces no more than a slight discharge, it may remain untreated.

Tuberculosis of the Vagina.—Tuberculosis of the vagina may be caused by an extension of the disease from the uterus or vulva (see Lupus of the Vulva), or primarily to the deposit of tuberculous semen. There is at first nodular infiltration of cells and bacilli, subsequent serpiginous ulcerative and cheesy necrosis, and a tendency to coincident cicatrization of widely separated areas, with intervening healthy tissue. As ulceration progresses it may open into the rectum or bladder. Pain and sensitiveness are singularly absent.

Diagnosis.—Microscopic and inoculation experiments with guinea-pigs are the only reliable means for arriving at a certain diagnosis.

Treatment.—This is the same as for lupus of the vulva. In cases of fistulous openings into the rectum or bladder, the disease should, if possible, first be cured, and the fistulas closed as ordinarily subsequently.

Benign New-growths of the Vagina.

Vaginal Cysts.—Vaginal cysts may properly be considered with benign new-growths, because of their importance from a diagnostic standpoint.

Inclusion cysts of the vagina, the result of perineal tears or after operations, constitute about one-half of the cases met with. Vaginal glands do not exist normally. In rare instances small glandular remains of Gartner's duct persist in the anterior or lateral vaginal walls, while aberrant cervical glandular formations are occasionally present in the posterior vaginal wall. Both formations, being of epithelial origin, may result in cystic conditions, and very rarely in adenomatous formations of a benign or malignant type. Vaginal cysts

are usually of relatively small size, but may attain the dimensions of a goose's egg. They may be single or multiple. The contents may be clear or yellow, viscid or watery, or, as the result of inflammatory changes, may be purulent.

Symptoms.—Vaginal cysts cause no symptoms unless they are large enough to give the sensation of a foreign body or interfere with coition. In cases of rupture with a mucoid discharge, the secretion usually persists. The prognosis is good.

Treatment.—A small cyst may be disregarded unless a vaginal operation for the relief of some other condition is indicated, when the cyst should be removed. The larger cysts should be removed by enucleation without rupturing the cyst-wall, if at all possible. The wound should then be closed with deep sutures, or the sac may be incised and emptied, swabbed with pure carbolic acid, and packed with gauze until the wound has healed from the bottom.

Fibromyoma of the vagina is the only true benign new-growth of the vagina, and is extremely rare. Like fibromyoma of the uterus, these tumors usually develop during the child-bearing period. They are usually single, of slow growth, and vary in size from a small nodule to the dimensions of an adult head. They may be sessile or pedunculated, and are exposed to edema, ulceration, and gangrene.

Symptoms.—The small tumors cause no symptoms. Those of larger growth usually give the sensation of a foreign body, interfere with coitus, and may cause pain, hemorrhage, leukorrheal discharge, dysuria or retention, obstruction of the bowels, and in some cases they prove an obstacle to labor.

Treatment.—If the tumor is small and without symptoms, its removal is not demanded unless an opportunity presents itself during an operation for some other pelvic condition. Removal of the growth is indicated in all cases giving rise to symptoms. If the tumor is pedunculated, it should, if possible, be delivered through the vulvar orifice, the tissues in the immediate vicinity fixed with tenacula or vulsella forceps, the pedicle severed with knife or scissors, and the wound closed so as to secure the bleeding vessels with a running suture of chromic catgut.

In the removal of sessile tumors the overlying vaginal structure should be incised and the growth enucleated. The size of the tumor may necessitate enlargement of the vaginal opening by lateral incisions before it can be removed. The cavity created by the enucleation, after ligating all bleeding points, should be closed with interrupted sutures. A small drain of iodoform gauze carried to the bottom of the wound and removed in forty-eight hours may prove of value in preventing the formation of a hematoma. After closing the vaginal incisions (if such were necessary) the vagina should be snugly packed with iodoform gauze in order to keep the wound walls in apposition. The end of the drain in the wound should be so placed that the same can be removed without disturbing the vaginal packing. The latter should remain about five days. Excessive hemorrhage

and serious injury to neighboring organs are the two principal dangers of the operation. The average tumor offers no special difficulties, but a sessile growth of large size may demand the best judgment and skill of a surgeon accustomed to dealing with gynecologic emergencies.

Pointed condylomata of the vagina are rare. They have the same characteristics as those of the vulva, and may be associated with them. They are usually multiple and widely distributed, are light pink in color, covered with normal epithelium, and have an uninfiltrated healthy base, all of which stand in strong contrast to the characteristics of cauliflower or ulcerative forms of carcinoma. A solitary papillary outgrowth, however, whatever its appearance may indicate, should always be looked upon with suspicion, and its prompt removal for microscopic examination should be insisted on.

Treatment.—This is the same as for condylomata of the vulva.

MALIGNANT NEW-GROWTHS OF THE VAGINA.

Carcinoma of the Vagina.—Primary carcinoma of the vagina is very rare. Of all deaths from cancer in a total of 8287, Bergel found 14, or 0.16 per cent., to be primarily located in the vagina. Many American gynecologists of large experience have never met with a single instance.

Child-bearing bears no relation to its development. I saw a case in which a pessary worn for more than twenty years had become embedded in a cancerous mass that involved both the vagina and rectum. In 73 per cent. of cases the new-growth is located on the posterior vaginal wall. Like carcinoma of the uterus, it is generally a disease of advanced life, but has been found in children.

Carcinoma of the vagina presents the same variability in its clinical manifestations as squamous-cell carcinoma in other portions of the body. It may appear in the form of an infiltrated nodule, and later as a granular, ulcerated surface, with foul detritus and infiltrated edges, or, as is usual, as a fungating, friable outgrowth. It is usually rapid in its progress, and through the perivaginal tissues, soon involves the neighboring organs. If located in the lower fourth of the vagina, the inguinal glands become involved, while extension to the deeper glandular structures usually follows when the primary focus is at a higher plane.

Owing to the extraordinary rarity of adenocarcinoma of the vagina, the following case may be of interest: Mrs. H., aged fifty-four, III-para; last child twenty-one years old; menopause eight years ago; had always enjoyed good health until three years ago, when she first noticed a slight hemorrhagic discharge from the vagina. On August 22, 1908, Dr. Catharine Macfarlane, of the Woman's Hospital of Philadelphia, removed a suburethral growth through an incision of the anterior vaginal wall. Although a clinical diagnosis of malignant disease was made, the microscopic examination proved uncertain. At the time I was consulted, March 26, 1909, she complained of a constant bloody discharge and painful micturition. My

examination disclosed a soft, friable mass the size of a walnut, occupying the lower third of the anterior vaginal wall below the urethra (Fig. 124), with an indurated ridge passing toward the left vaginal fornix. The urethral mucous membrane was not involved in the growth, and the uterus was freely movable and perfectly normal. The glands of both inguinal regions were found to be markedly enlarged and painful. Dr. John Funke reported it to be an adenocarcinoma. In view of the absence of glandular structure in the vagina normally, and considering the position of the mass and the direction taken by the induration, the growth in all probability had its origin in the remains of one of Gärtner's ducts.

Fig. 124.—Primary Adenocarcinoma of the Anterior Vaginal Wall.

Symptoms and Diagnosis.—Irregular bleeding after coitus usually is the first symptom; later, pruritis, mucopurulent discharge, gradually becoming offensive. With involvement of the deeper tissues the patient suffers from dull aching pain in the pelvis and in the lower extremities, and from dysuria and painful defacation. Finally, the formation of urinary or fecal fistula, the development of septicemia and uremic conditions, with consequent anorexia and loss of rest and sleep, lead to exhaustion and death.

The presence of a nodular, granular, papillary growth or ulcerative excrescences of the vagina, especially in a woman after the age of forty, in the absence even of any other sign or symptom, demands immediate excision of a portion of the growth and microscopic examination by a reliable pathologist to determine the diagnosis and indications for further operative interference.

Prognosis and Treatment.—No well-authenticated case of cure has been reported, even after the most radical treatment. This in a measure may be accounted for by the thinness of the vaginal walls, the large perivaginal lymphatics, and by the latency of the symptoms as compared with the progress of the disease. Krönig, Pryor, and Montgomery advocate extremely radical procedures, but none has reported any cures. Krönig's operation includes the removal of the

entire vagina, uterus and appendages, adjacent rectum, and bladder. Montgomery, in a case of cancer of the rectovaginal septum, removed the coccyx, resected the sacrum, excised six inches of the rectum, removed the ovaries and tubes, and the entire posterior wall of the vagina. The rectum was stitched to the sacrum posteriorly, and to the anterior wall of the vagina anteriorly, the perineum having been previously closed. There was a recurrence of the disease within thirteen months. Pryor, in two cases, by a combined external and intra-abdominal pressure, began his operation by ligating all the main arteries to the genital organs in order to secure a dry field. He then removed the lower half of the labia, the greater portion of the vagina, the entire rectum with the sigmoid, together with the uterus and appendages, and in both death followed local recurrence in less than a year. As a palliative measure the growth, if localized, may be excised, and the base cauterized with the thermocautery or with chlorid of zinc.

Primary Chorio-epithelioma of the Vagina.—The occurrence of primary chorio-epithelioma of the vagina and in other more remote structures of the body, while the uterus itself escapes infection, has been observed in a number of cases. Busse and Marchand have each recorded a case of cerebral and pulmonary involvement several months after the removal of a hydatid mole in the one, and following an abortion in the other, the autopsy in each showing that both uterus and vagina were free from the disease. While the possibility of contact infection of the vagina must be admitted, the foregoing tends to establish the truth of the theory that the disease as it occurs in the vagina and other more remote structures from the uterus originates in the deposit of migratory chorionic villi from the uterus through the blood-channels, the epithelium of the villi subsequently undergoing malignant proliferation. H. T. Hicks, accepting this theory, in an excellent paper on "Primary Embolic Chorio-epithelioma of the Vagina," reports a case of his own and refers to fourteen others. In all these fifteen cases the vaginal tumors were simply excised. The diagnosis in each case was confirmed by reliable pathologists. Three of the patients died with secondary growths in the lungs, liver, and kidneys, but the uterus escaped. The other twelve made complete recoveries. He likewise calls attention to the extraordinary malignancy of these growths in the uterus in some cases, and their innocent behavior in exceptional instances in others, and refers to the disappearance of secondary vaginal deposits in certain cases after hysterectomy for the removal of a primary uterine involvement.

The *question of the malignancy of these growths in the vagina, therefore, is a matter of great clinical importance,* both as to prognosis and to treatment. Microscopic appearances as at present understood appear to be of no assistance to the clinician in deciding this question. Mr. Hicks very properly says: "One wonders whether these primary vaginal growths are not, as a rule, almost benign," although the case reported by him proved violently malignant.

Diagnosis.—The history of a molar pregnancy especially, but the appearance of a growth in the vagina of almost any description, either during pregnancy or subsequent to the discharge of the product of conception at any time, should at once arouse the suspicion of such a growth. The vaginal nodules usually appear two or three months after the uterus has been emptied, although Hicks refers to two cases in which vaginal growths appeared three and a half and four years respectively after the passage of the mole. This is explained on the theory that migrated chorionic villi may lie dormant in the tissues for long periods before undergoing a malignant change.

Treatment.—If the vaginal growth is primary, the prognosis is probably good, and its excision, together with a wide area of healthy vaginal tissue, alone may be indicated; but if it is secondary to a uterine involvement, the prognosis is bad and demands removal of both the uterus and vagina.

Sarcoma of the Vagina.—Sarcoma of the vagina is more rare than primary carcinoma. It has been found congenitally and as late in life as the eighty-second year. Of cases reported, more than 75 per cent. have appeared in children less than fifteen years of age. In children, the growth is of a dull red or chocolate color, is usually situated in the anterior wall, is circumscribed and polypoid in form, while in adults it presents itself in the form of a diffuse sarcomatous infiltration closely resembling carcinoma, or as a rounded, sessile growth that sooner or later ulcerates. The tissues in the immediate vicinity of the growth are invaded early, and recurrence after operation is the rule.

Symptoms.—The symptoms vary with the size and location of the growth. Frequent and painful micturition and constipation may be present. Necrosis or ulceration of the growth gives rise to foul discharges and opens up avenues for the entrance of pathogenic organisms and systemic infection. The destructive processes coincident with the extension of the disease may lead to the formation of fistulous openings with the rectum and bladder. The loss of rest and sleep from pain, the general toxemia and anorexia, sooner or later cause extreme emaciation, exhaustion, and death.

Treatment.—Early eradication of the disease by one of the various surgical procedures for the removal of carcinoma of the vagina is indicated.

FOREIGN BODIES IN THE VAGINA.

The variety of objects that have been found in the vagina would form a long list, including widely dissimilar articles, both in size and substance, of which needles, grasshoppers, pine-cones, pessaries, drinking-glasses, pocket-books, bacon rind, cockchafers, and insects are a few examples. Masturbators make use of all sorts of articles to satisfy their morbid desires. They are usually only partly introduced into the vagina, but by exciting contraction of the levator muscles, they suddenly slip from the hand, are carried beyond the introitus, and thus become imprisoned in the vagina.

To prevent conception, women resort to the use of sponges, tampons, hard- and soft-rubber diaphragms and plugs, the removal of which may be neglected or forgotten. For the induction of abortion, catheters and pointed and sharp instruments of various kinds are resorted to, and, becoming broken in the attempt, portions remain in the vagina. Thieves and pickpockets have been known to use the vagina for concealing their plunder. The undue retention of articles introduced for therapeutic purposes, such as tents, tampons, and pessaries, is very common. Intestinal worms, and by ulcerative perforations hair and teeth of a dermoid cyst, the bones of an ectopic fetus, and foreign bodies in the bladder and rectum may find their way into the vagina.

Symptoms.—In accordance with the substance, size, form, and length of time they have been within the vagina, foreign bodies may give rise to a great variety of symptoms. Retained sponges and tampons cause hypersecretion and putrid decomposition that may arouse a suspicion of incomplete abortion, sloughing polyps, or the presence of malignant disease. If the object is hard, rounded, and smooth, and remains unchanged by contact with the vaginal secretions, like ivory, and does not exert much pressure, it may be retained for years without causing any annoyance. Hard-rubber pessaries and other corrodible objects sooner or later become eroded and irritating from the deposit of lime salts. Such incrusted articles, or the continuous pressure at one point of a smooth body even, is sure to cause ulcerations, with consequent purulent and offensive discharge. If the offending body is not removed, perforations into neighboring organs may occur, and the patient's life may be jeopardized from peritonitis and suppurative processes, or the ulcerations may cause exuberant granulations, adhesions, and contractions of the vaginal walls, with encapsulation of the foreign body.

Diagnosis.—The diagnosis is made by sight and touch. In addition to a vaginal examination with finger and speculum, it may be necessary to examine the vagina indirectly through the rectum or bladder or by combined manipulations, especially in cases where foreign bodies have become hidden by incrustations, granulation tissue, or vaginal contractures.

Treatment.—This consists in removing the foreign body and in correcting the lesions it has caused. While the first indication in most cases may be met by very simple means, in others it may tax the ingenuity and skill of surgeons of large experience. Small and moderately sized free objects are usually extracted without difficulty with fingers or forceps. Pressure through the rectum often proves of value in dislodging and expelling objects held back by contractions of the vagina. Firm bands of adhesions may be divided. Large objects should be reduced in size by crushing or cutting. In a patient at the Jefferson Hospital who had worn a large ball pessary for a number of years a miniature obstetric forceps was used for its removal. In another case with a foul-smelling discharge that aroused a sus-

picion of carcinoma a Smith-Hodge pessary was found deeply buried in a mass of exuberant granulations and tough cicatricial bands, only a small segment of the instrument remaining exposed. The visible portion of the pessary was cut with bone pliers; it was then rotated so as to bring its opposite extremity into view, when this was likewise severed. Both halves were now very easily removed without lacerating the tissues. Pieces of broken glass in the vagina, if they cannot be picked out with the forceps, should be removed by first lubricating the vagina with liquid albolene and then filling it with plaster-of-Paris. This embeds the glass fragments, after which both may be removed with comparative little injury to the vagina. Hair-pins usually have their points directed forward; these must be disengaged before they can be removed. In cases of cicatricial contractions of the lower segment of the vaginal tube, the foreign body may be pushed to a higher level, burrowing between the tissues, so that its removal through the bladder or rectum or by abdominal section may become necessary.

After the removal of the foreign body, in the simpler cases, the existing vaginitis soon disappears, but its cure may be hastened by the use of antiseptic douches, preferably saturated solutions of boric acid. In the complicated cases, ulcerations, fistulas, metritis, peritonitis, and sepsis may demand subsequent attention.

Traumatisms of the Vulva and Vagina.

Owing to the protected situation of the parts, injuries of the vulva and vagina, independent of those occurring in childbirth and from violent coitus, are comparatively infrequent.

The **vulva** is subject to all the varieties of wounds met with in other exposed portions of the body as the result of falls, blows, kicks, and other forms of external violence. In children sliding down the handrail of a staircase, the vulva striking the projecting knob of a newel-post, or falling astride some other hard object, usually results in contused wounds, while the penetration of some sharp instrument may cause an incised, punctured, or lacerated wound. The former variety of injury may be complicated by a subcutaneous hemorrhage, which, on becoming clotted, forms a pudendal hematoma. The latter, being an open wound, may be followed by alarming and even fatal hemorrhage.

Prognosis and Treatment.—A *pudendal hematoma*, if small, may disappear by absorption. In pregnant or puerperal women the enlargement may attain the size of an ordinary orange, and the larger the tumor, the less its likelihood of spontaneous cure. Rest in bed in these cases is the first indication. An ice-bag applied immediately or shortly after the accident limits the extravasation of blood and promotes its absorption by the continuous pressure, and prevents suppuration in many cases. If absorption does not take place within seven or eight days, a free incision should be made, the clot turned out, and the cavity irrigated and packed with sterile gauze. The

packing should be renewed daily until the wound has healed. If suppuration supervenes, the part should be freely opened and drained.

The hemorrhage from an *incised wound* of the vulva is best controlled by pressure until the spurting vessels can be tied and the wound closed by a running suture of catgut. Punctured and lacerated wounds must be considered individually, and should be closed or treated openly in accordance with the principles governing the care of such wounds in other exposed portions of the body.

Traumatisms of the vagina of non-puerperal origin are rare. They are generally inflicted during coitus, involving the hymen and tissues in the immediate vicinity, but may result from the application of any form of external violence and involve any portion of the vaginal tube. In some cases vaginismus predisposes to the injury during coitus. The consequent hemorrhage may be temporarily, and in some cases permanently, arrested by the pressure of a tampon, but usually ligation of the bleeding vessels or closure of the wound with stitches becomes necessary.

Accidental complete laceration of the perineum, independent of parturition, is very rare. It usually results from violent impacts against hard, sharp, or penetrating objects. One of the most frequent causes in children is striking a sharp-edged newel-post while sliding down a banister. It has resulted from a fall on the leg of a stool or on the back of a chair, by the penetration of the handle or prong of a pitchfork, or of a knife concealed in a hay-mow. Broken chambers or waste-jars, kicks, falls, and impalement by horned cattle, have been among the inflicting agents. Bovée, in an excellent review of the subject, reports a case of a child, eight years old, whose feet slipped while standing on the coasters of a bicycle. She lodged on the lamp bracket, which caught in the rectum and vagina and severed the rectovaginal septum for more than an inch. Royster reports a case in which the obstetrician mistook a breech for a face presentation, and introduced his finger into the supposed mouth (vagina) for traction, and thus ruptured the rectovaginal septum, including the perineum. Cases have been reported in which the injury not only involved the rectovaginal septum, but the peritoneal cavity, with severe traumatisms to the contained viscera, and yet recovery followed.

Treatment.—In the vast majority of these cases immediate closure of the wound is inadvisable. The wound-edges may be ragged and the tissues in the immediate vicinity bruised, and in some cases devitalized. Under such circumstances the indications are to arrest the hemorrhage and to treat the parts with antiseptic evaporating lotions until the tissues have regained their vitality. If sloughing supervenes, nothing can be done until the parts have cicatrized. In clean-cut wounds an immediate repair may be done with a reasonable hope of securing good results. Correct coaptation of the rectal wall and union of the sphincter ends are the most important indications. (See Operations for Complete Lacerations of the Perineum.)

It is well to bear in mind that serious infections may result from these injuries of the vulvovaginal structures. Neugebauer has collected 157 cases, 22 of which resulted fatally from septic processes or hemorrhage.

PUERPERAL INJURIES OF THE PELVIC OUTLET.

In order to comprehend the clinical significance of puerperal injuries of the pelvic outlet, as well as the principles underlying the various operative procedures for their repair, it is of first importance to have a clear conception of the gross anatomy of the pelvic structures, especially with reference to the tissues that invest and determine the position of the genito-urinary organs, and by which their normal anatomic relations are maintained. For present purposes and as a working formula clinically a general description of the parts is essential.

Anatomy.—Upon removing the superimposed tissues, *e. g.*, the bladder, uterus, and its appendages, the upper three-fourths of the vagina, together with the peritoneum and pelvic connective tissue, and looking into the pelvic cavity from above, the pelvic diaphragm (floor of the pelvis) closing the pelvic outlet presents itself in the form of a shallow muscular basin with three eccentric outlets—the rectum behind, and the urethra and vagina in front. The pelvic fascia upon either side, after becoming more or less firmly fixed to the pelvic brim, passes into the pelvic cavity and secures bony attachments on the posterior surface of the pubes and at the spine of the ischium. Between these two points the fascia becomes thickened, forming the white line of the pelvis. Here, approximately, the fascia splits into three layers. The outer leaflet, continuing downward, covers the obturator muscle and finds attachment to the pubic rami, ischial tuberosity, and sacrosciatic ligament, and forms the outer boundary of the ischiorectal fossa. The other two leaflets cover the upper and under surfaces of the musculature of the pelvic diaphragm, that on its lower aspect constituting the inner boundary and completing the ischiorectal fossa. The muscular portion of the diaphragm comprises three pairs of flat muscles, the edges of which are practically in contact and may have grown together, forming one continuous layer. The arrangement of the muscular fibers is of special importance, because it indicates the direction of their vital energy and mechanic influence, and constitutes the key to a proper understanding of pelvic support. The anterior segment of the pelvic floor, better known as the levator ani muscle (puborectalis or pubococcygeus), is attached to the posterior surface of the body of the pubes. It is directed downward and backward along the sides of the vagina and rectum, a few of its fibers going between these two structures to enter into the formation of the perineum, but by far the greater mass of this muscle passing posterior to the rectum to coalesce with its fellow of the opposite side, the musculature of the rectum, and with the anal sphincter. The "pull"

of this muscle gives the rectum at its lower end its characteristic sigmoid forward curve.

The second part of the muscle (obturator coccygeus) arises from the tendinous white line in the interval formed by the separation of the two layers of fascia covering its surfaces. Its direction is likewise downward, backward, and inward, some of the fibers uniting posteriorly to the rectum without an intervening tendon, thus aiding the anterior portion of the muscle in the formation of the rectal forward curve, while the remaining fibers are attached to the median tendinous raphé posterior to the rectum and to the sides of the coccyx.

The third portion of the muscle (ischiococcygeus) is of secondary importance surgically. It arises from the spine of the ischium and spreads out fan-shaped, to be attached to the sides of the coccyx and the lower portion of the sacrum. The remaining portion of the pelvic basin posteriorly is completed by the pyriformis muscle.

While the pelvic diaphragm constitutes the true muscular floor of the pelvis, with its anterior segment as the main object of attack in restoring lost pelvic support, it is but one of a system of structures that are concerned in maintaining the normal anatomic relations of the pelvic viscera. A practical knowledge of the anatomy and functions of the investing structures above and below the diaphragm, therefore, is likewise necessary. Beginning above, we find that the uterus with its appendages, not unlike all other specialized structures of the peritoneal cavity, is suspended and directly supported by mesenteric folds and attachments (so-called ligaments) that, in their vitalized state, other anatomic conditions being equal, give these organs certain limitations of mobility and prevailing tendencies of position which are regarded as normal.

Below the peritoneal covering, and between it and the pelvic floor, is a variable amount of loose connective tissue that fills up otherwise free spaces. A comparatively thin layer unites the anterior vaginal wall and the base of the bladder. Considerable masses are found on both sides of the uterus and corresponding bases of the broad ligaments. The greater portions of the vagina and rectum are embedded in large accumulations of connective tissue, which is here loaded with a variable amount of fat. Generally considered, and in its practical application to the study of injuries of the pelvic floor, it may be said that the connective tissue, although appearing in broken planes, increases in bulk from above downward, forming a funnel-shaped mass from the pelvic brim to the insertion of the muscles forming the pelvic diaphragm.

Second in importance to the pelvic diaphragm in the study of pelvic support is the vaginal roof. The attachment of the vagina to the pubes anteriorly, its continuity with the musculature of the uterus, and the ligamentous and sacral fastenings of the latter posteriorly, form an irregular though continuous muscular layer, extending from the pubic bone to the sacro-iliac synchondroses. The vaginal roof thus formed is reinforced by a fibrous prolongation from

the fascia covering the pelvic diaphragm, by its close association with the base of the bladder, and indirectly by the ligamentous processes of the pelvic viscera above it, the urachus, and the attachment of the anterior face of the bladder to the posterior surface of the symphysis.

The parts below the pelvic diaphragm comprise the anal and urogenital regions. The line of division corresponds to a transverse fibrous band (ischioperineal ligament) attached to the ischial rami just in front of the tuberosities. The posterior space is occupied by the anus, the terminal portion of the rectum, the anal sphincters, and the ischiorectal fossæ. Anteriorly, this band is the line of origin for three layers of fasciæ, all of which are inserted into the ischiopubic rami. The two deeper layers (deep pelvic fascia, triangular ligament) fasten the vagina externally, and with the muscular slips between them form the vaginal septum, while the superficial layer serves as a base of attachment for the loose drapery surrounding and forming the vulvar orifice. Between these fascial layers are muscular bundles of no special importance for the present study, excepting the superficial transversus perinei muscles, which arise from the ischial tuberosities and are inserted into the outer edges of the bulbocavernosus muscles and the anterior perineal structures, of which they form a part. The anterior portion of the deepest of these fascial leaflets coalesces with the fascia on the under surface of the diaphragm, thus limiting the extension forward of the ischiorectal fossæ.

The name perineum has been given to that portion of the ensemble of structures just described, lying between the vulvovaginal orifice and the terminal portion of the rectum and anus. It presents marked variations in all its dimensions in different individuals.

Functions of the Pelvic Connective Tissue and the Pelvic Diaphragm.—The pelvic connective tissue forms a soft padding between organs that, to a degree, supports them and permits of their free mobility and physiologic repletion and depletion, without undue encroachment upon associated structures. Its relation to the venous system of the pelvis in determining a properly balanced circulation is of special importance. Its open-mesh and fascial planes, aided by the rise and fall of the diaphragm, give these valveless plexuses elastic support, supplement the *visatergo*, and, by preserving the tortuosity of the venous trunks, counteract the force of gravity and thus prevent undue vascular dilatation and passive pelvic engorgement.

The pelvic diaphragm, in addition to its influence on the pelvic circulation, protects the internal pelvic organs. It is the antagonist of the thoracic diaphragm, contracting under expiration and relaxing during inspiration. It counteracts intra-abdominal pressure; the greater this pressure within certain limits, the more vigorously the muscle contracts, and the more firmly its anterior segment (the levator ani) closes the vaginal outlet. In doing so it likewise fulfils the functions of a buffer, by preventing undue downward excursions of the organs above it. During defecation, especially in the extrusion

of large fecal masses, the rectal contents are evacuated by the combined forces of intra-abdominal pressure and counterpressure on the part of the levator ani muscle, by which the rectum and anus are temporarily elevated and fixed for the purpose.

It is well to bear in mind that the so-called perineal body as a distinct anatomic formation does not exist. As already indicated, it is merely the meeting-place of muscles and fascia common to the parts below the pelvic diaphragm, covered by more or less skin and a variable amount of connective tissue and fat. In itself it has nothing whatever to do with the support of the internal pelvic organs, and its efficiency in maintaining the normal relations of the external structures depends upon the anatomic and physiologic integrity of the levator ani muscle. As pointed out by Skene, the mechanism of this anatomic association of pelvic floor and perineum conforms with the principles that govern the supporting property of the suspension bridge, the anchorage being represented by the pelvic bones, the perineum representing the bridge and the levator ani muscles corresponding to the sustaining cables which hold the bridge at a slightly variable, though generally fixed, level. The anterior segment of the pelvic diaphragm, therefore, is not alone concerned in supporting the pelvic structures above it, but likewise in holding and sustaining the perineum and other parts below it.

Practical Study of Pelvic Support.—Upon making an inspection of the parts under normal conditions, the labia may or may not lie in contact, but the vaginal entrace itself will be closed. The perineal measurement between the vulvar orifice and anus may be comparatively long or very short, in accordance with the accidental presence of more or less integument, connective tissue, and fat, and the anus will be found tucked up in a deeply angled cleft between the buttocks.

Introducing a finger into the vagina, a firm muscular transverse elevation, apparently beneath the mucous membrane, about three-quarters of an inch in width, is felt crossing its posterior wall, just behind the hymen or its remains, but which, in reality, is the levator loop hugging the rectum posteriorly, and through it forming the vaginal promontory closing the vaginal outlet. By directing the woman to "draw up," it at once becomes evident that this muscular loop fulfils the function of a sphincter to the vagina, not alone by its own inherent tonicity, but that it is to a greater or less extent under voluntary control. Digital examination per rectum confirms the foregoing observations, while rectoperineal palpation with the index-finger in the rectum and the thumb over the parts discloses the proportionate amount of loose tissue entering into the formation of the perineum, as well as the shallowness of its muscular development, and at once dispels any previously held idea of a well-defined perineal body.

Upon retracting the posterior vaginal wall, which necessarily includes the perineum, the rectum, and the levator ani muscle, it will

be noticed that the muscular formation just mentioned is not absolutely essential, under strictly normal conditions, to the support of the anterior vaginal wall or the viscera above it. The muscular and fascial attachments of this portion of the vagina, together with its indirect supports, especially in nulliparous women, are usually sufficient to hold these structures at a proper elevation. In fact, exceptionally, women with lacerated or relaxed diaphragms even are met with yet in whom there is no evidence of descent of either the uterus or the vaginal roof. In cases, however, of rupture or other changes that bring about a weakened state of the musculature of the vaginal roof, or even under the stress of extraordinary muscular efforts, the pelvic diaphragm, especially its anterior segment, resists the tendency to excessive downward movements, and thus becomes the sole mainstay of the pelvic contents, including the vaginal roof itself.

Pathology and Symptoms of Injuries of the Perineum and Pelvic Floor.—Considering the foregoing, it becomes evident that injuries of the perineum, as compared with those of the pelvic floor (levator ani), necessarily cause totally different symptoms. Tears of the perineum may be superficial, deep, or complete.

A **superficial tear** involves little more than the fourchet or introitus vaginæ, and causes no symptoms. A more pronounced or *deep tear* usually involves the bulbocavernosus and transversus perinei muscles, where they coalesce in the perineal structures. These muscles, now acting independently of each other, pull the vulvar lips apart, exposing the vaginal entrance, the same as a doorway may be exposed by separating at the bottom the pair of portieres that conceal it. The deep perineal tear may extend down to the anal margin, exposing in some cases the sphincter ani muscle, but with the exception of the gaping vulvar orifice, this variety of laceration even rarely gives rise to more than a temporary inconvenience.

A **complete tear** of the perineum is a "deep tear" plus a rupture of the sphincter ani muscle. Very rarely the sphincter ani is torn without any involvement of the cutaneous perineum. The one distressing and overshadowing symptom of a complete tear is loss of control of the rectal contents. In the subsequent cicatrization of the parts the sphincter ends may become so fixed in scar tissue as to afford partial and in some instances very satisfactory control. A constipated habit frequently gives relief from involuntary fecal evacuations, but usually fails in preventing the escape of flatus. In some cases an uncontrollable diarrhea is the rule, causing constant fecal discharges, with resulting irritation of the external parts. Lacerations of the perineum, even though complete and involving more or less of the rectovaginal septum, interfere but little with pelvic support. The levator ani muscles, excepting the few fibers that enter the perineal structure, remain unharmed. They, therefore, retain their property of maintaining a closed condition of the pelvic outlet almost as perfectly as though no injury to the perineum had occurred.

Injury of the Pelvic Floor.—Considering the relations of the levator muscles, their injury during childbirth necessarily involves the lateral fornices of the vagina, and may be unilateral or bilateral, visible or submucous, superficial or deep. The submucous variety consists of an injury of one or both muscles without a visible tear of the overlying vaginal wall. A laceration of the pelvic floor may and usually does involve more or less of the structures forming the perineum, but unless the perineal tear in a given case is of the complete variety, its association with a laceration of the pelvic floor is of minor importance and will not be referred to again in considering the pathology and symptoms of the latter condition.

During the final stage in the delivery of the fetal head the uterine and abdominal forces push the presenting part downward, while the pelvic diaphragm, aided by the pelvic curve of the sacrum, deflects it forward to engage the levator loop. As labor progresses the latter is dilated, while the retractile property of its muscles is exercised in pulling the rectum and perineum first backward, then upward and forward over the escaping head. If, at this critical moment, the elasticity of the levator loop fails to accommodate itself to the size of the advancing head, rupture of its structure results, and if it escapes this accident, but becomes overstretched and fails in its tonicity or retractile power, a condition of permanent relaxation or paralysis supervenes. In either case the working efficiency of this portion of the pelvic diaphragm is destroyed, and certain abnormal changes of a more or less grave character are sure to follow.

Owing to the failure of the levators to respond to the movements of the respiratory act, the primary effect of such an injury is venous stasis, followed in some cases by an arrest of involution and a lowered resistance to the inroads of pathogenic germs. The most pronounced changes, however, directly referable to the accident, usually occur after the lying-in period. The ruptured or overstretched muscles, in accordance with the extent of their involvement, permit the perineal bridge to drop to a lower level; the anus is drawn toward the coccyx, the anal cleft becomes more or less obliterated, and the cutaneous perineum, if uninvolved in the laceration, usually becomes deeper; in other words, more or less pronounced sagging of the structures of the entire perineal region takes place. As a consequence, the venous trunks within the pelvis are drawn out and lose their tortuous course, while failure of the "rise and fall" of the pelvic diaphragm deprives them of their elastic support, so that they become dilated, varicose, and a source of passive engorgement. The resistance of the pelvic floor to intra-abdominal pressure is no longer present, and its functions of making counterpressure during defecation and of acting as a sphincter to the vagina are likewise absent. It fails to respond to stimuli, and is no longer under voluntary control. The vaginal entrance either is a gaping orifice or markedly relaxed, and the vaginal promontory is effaced.

Depending upon the extent of the injury and the length of time

it has existed, a hernial protrusion through the dilated vaginal orifice of one or more of the pelvic organs takes place. At first the posterior vaginal wall prolapses (posterior colpocele), and this may be followed by the associated rectal wall, when it is termed a rectocele. But in the vast majority of cases the so-called rectocele is not a rectocele at all, but a prolapsus of the vaginal wall and an overdistended varicose condition of the veins between the vagina and rectum. In the presence of a fecal accumulation the rectum, unopposed anteriorly, may cause a forward protrusion, especially during defecation, but upon making an examination after the rectum has been emptied no diverticulum of this structure can be detected, and the apparent rectocele disappears as the blood is pressed out of the veins, and as promptly reappears upon relieving the pressure. This condition of the veins, as already indicated, obtains throughout the lower pelvic segment and accounts for the feeling of weight and fullness so frequently complained of.

Owing to arrested involution or failing tonicity of the musculature forming the vaginal roof consequent upon the loss of its supplementary support from below, or to coincident detachment or relaxation of some of its direct supports, prolapse of this structure usually follows; but, as previously stated, its integrity and supporting property may be preserved in the presence even of an extensive injury to the pelvic floor.

The unrestrained latitude for downward excursions of the uterus, in addition to traction upon the organ by the constantly prolapsing posterior vaginal wall, generally imposes impossible demands upon the retractile property of otherwise efficient ligaments, resulting in overstretching and finally in atrophy of their muscular structure and consequent ptosis or prolapsus of the organ, that in some cases amounts to an extrusion of the entire organ through the vulvar orifice (procidentia), dragging the vaginal walls with it. In other cases the vaginal walls prolapse, first dragging down the uterus (vagino-uterine prolapse). The importance of these distinctions in the forms of prolapse will be more fully appreciated in discussing the treatment.

As a matter of course, the local changes vary with the extent of the lacerations, and whether they are unilateral or bilateral, while the severity of the symptoms usually corresponds with the organs involved and the degree of prolapsus, as well as with the nature of existing complications. Ordinary backache, a feeling of weight and fullness in the pelvis, and bearing-down sensations are frequently complained of. Reflex headaches and gastric disturbances are common, and constipation is the rule. Vesical irritation and difficulty in thoroughly emptying the rectum without manual support from the vaginal side are likewise frequent symptoms. Disturbances of the functions of the uterus, when present, are accounted for by the passive congestion and changes of structure incident to the prolapsus. In some cases there are no symptoms, although in injuries of one or both levators of minor degree the overaction of the intact portion may cause very annoying reflex irritations.

Treatment of Injuries of the Perineum and Pelvic Floor.—Operations for the repair of injuries of the vaginal outlet are usually classified as primary, intermediate, and secondary.

The **primary operation** should be performed in all cases if the condition of the patient at the conclusion of labor permits it. It is done immediately, or not later than twenty-four hours, after the delivery. Among the advantages of the primary operation are the closure of possible avenues for infection, the avoidance of subinvolution and venous stasis, with their retinue of deleterious sequelæ, and, if done immediately, the parts are usually so benumbed from the pressure incident to labor that an anesthetic may be dispensed with. The operation is contraindicated in cases of eclampsia, postpartum hemorrhage, great prostration, virulent infection, and when the lacerated tissues have become devitalized from pressure. Postponement of the operation for a few hours is frequently indicated for want of proper assistants, instruments, dressings, etc. In all cases of lacerations involving the sphincter ani and rectum, however, repair of these structures should be done immediately, irrespective of local conditions, if the patient's constitutional state will justify such a procedure. No harm can result from such practice. Infection from feces may be avoided, and union of the parts frequently takes place in the presence of apparently hopeless local conditions.

Preliminaries.—Nothing should be left undone to insure the performance of the operation under the most favorable conditions. None other than sheets and towels that have been sterilized should be used if at all possible, but if these are not available, recently laundered clean linens may be used after being gone over with a well-heated flat-iron, and covered with towels wrung out of a 1:1000 bichlorid solution. Thorough cleanliness and the strictest aseptic and antiseptic precautions should be observed on the part of the surgeon and his assistants in their personal attentions, as well as in the preparation of receptacles for solutions and instruments. An abundance of clean hot and cold water, previously boiled, should be at hand. Instruments, irrigating apparatus, and rubber gloves should be sterilized by boiling. Some of the most virulent infections have come under my own observation as a result of neglect on the part of practitioners concerning these simple precautions.

The instruments necessary for doing a primary repair are scissors, a few hemostats, needle-holder, a few curved needles, and occasionally a retractor. The suture material may be left to the choice of the surgeon. Chromicized catgut No. 1 has the advantage of holding the tissues in apposition until union has occurred, without irritation of the tissues or otherwise annoying the patient.

Under no consideration should the operation be attempted with the patient lying in bed. The modern bedstead is too low for the purpose, and is back-breaking to the surgeon, while the soft, shifting mattress is an additional obstacle to the proper performance of an operation requiring such nicety of adaptation. One of the best

supports for the patient is an ordinary kitchen table, four or five feet long by one and a half to two feet wide. This offers a properly elevated, non-shifting surface, can be so placed as to secure the best light for thorough inspection, and affords the surgeon and his assistants the necessary access for doing good work. By the use of a Robb leg-holder, but one assistant may be necessary. After the patient has been anesthetized, if an anesthetic is necessary, the vagina, external genitals, and immediate surroundings, including the hypogastrium and the inner and anterior aspect of the upper thighs, should be thoroughly scrubbed with a solution of soap in sterile water, followed by some antiseptic solution, preferably bichlorid 1:1000, and, lastly, the field for exposure should be surrounded with sterile sheets.

Operation.—With all the necessary operating paraphernalia properly arranged, the surgeon, conveniently seated, separates the labia and exposes the entire genital field, using a retractor for the purpose if necessary. Rents of the cervix, if their repair is indicated, are first attended to. If the perineum or vaginal walls are lacerated, a plug of gauze, or, preferably, absorbent cotton wrung out of a solution of bichlorid, is introduced into the vagina well above the upper limits of the torn surface, to be removed with a forceps upon the completion of the operation. This secures a comparatively dry field and facilitates examination of the parts and proper surgical manipulations.

Tears of the anterior vaginal wall, if present, are sutured first; those of the vaginal sulci next, and perineal tears last. The exception to this order of procedure is in cases of lacerations of the perineum involving the sphincter ani and rectal wall, to be referred to later. Frayed and irregular edges should be smoothly trimmed with the scissors, and all sutures should be introduced so as to bring the separated structures as nearly as possible into the normal anatomic relations. This at times is difficult, owing to muscular retractions and consequent displacement of tissues.

To one unaccustomed to this line of work, an excellent plan to follow in cases of extensive or complicated tears is to place one hand upon either side of the external parts and push the torn surfaces together in such a way as temporarily to restore the normal relations. The terminal angles of the torn tissues at the vaginal entrance are now transfixed by guide sutures, to serve as indicators of the lower limits of the vagina, which, when drawn together, bring the torn surfaces into correct apposition and disclose the depths and proper relations of the structures to be sutured.

Tears of the anterior vaginal wall are usually closed with continuous sutures of chromic catgut. The vaginal sulci should be repaired, so as to bring the retracted ends of the torn levators and the fascia into firm coaptation. This is best done by the use of a curved needle, placing the sutures about one-third of an inch apart. The needle penetrates the mucous membrane about a quarter of an inch from the margin of the tear on one side, makes a semicircular sweep

out into the tissues from above downward to the bottom of the sulcus, repeating the same procedure from below upward on reëntering the tissues and emerging from the corresponding margin of the mucous membrane of the opposite side. Stitches thus placed, when tied, belly the muscular structures toward each other between the bottom of the sulcus and the free edges of the torn mucous membrane, securing firm coaptation throughout the whole line of suture. The two ends of each suture should be secured by a hemostatic forceps till it is ready to be tied. None of them should be tied until all have been introduced.

In bilateral tears, first one side, and then the other, should be sutured. The external perineal wound should now be closed with transverse sutures, by observing the same general principles that apply to suturing of tears within the vagina, being especially careful to catch and reattach the retracted ends of the superficial transversus perinei muscles.

In complete tears of the perineum, to prevent soiling of the raw surfaces and possible infection from fecal discharges, the torn rectal wall and sphincter should be united before attempting to repair tears within the vagina. Tears of the rectal wall may be closed from above downward in one of three ways: (1) By interrupted sutures which are passed through the entire thickness of the rectal wall and tied within the lumen of the gut; (2) by interrupted Lauenstein sutures; (3) by continuous Lauenstein sutures. The Lauenstein suture includes the margin of the torn edge of the rectum, as well as the rectal wall itself, excepting its mucous coat, and whether the stitches are interrupted or continuous, the fixation knots are tied within the lacerated area facing the vagina.

After the rectal wall, including the anal margin, has been restored, the next step is to reunite the torn ends of the sphincter ani. It should be recalled that, under normal conditions, this muscle surrounds the terminal portion of the bowel immediately beneath the skin, so that its retracted ends in cases of rupture are usually found in small deep sulci just within the torn edges of the skin, upon either side of the anal margin. The retracted ends, after being lifted up from the depths of these sulci with a tenaculum or toothed forceps, are reunited by two or three chromic catgut sutures. The line of union in the rectal wall may be reinforced, and tension minimized by a running suture of catgut, uniting a portion of the deeper tissues overlying the rectum.

Upon the completion of the operation the parts are washed with an antiseptic solution, after which an aseptic vulvar pad is applied. The patient is put to bed, and is now cared for in accordance with indications following delivery.

After-treatment.—The patient is permitted to lie in any position. Tying the legs together is unnecessary. The catheter is not used unless the patient is unable to pass urine. The external parts should be irrigated with an antiseptic solution after each urination and bowel

movement. Douches should not be given unless especially indicated. The bowels should be moved on the third day after the operation by the use of some cathartic, preferably Epsom salts, and daily evacuation should be secured subsequently by enemas for not less than a week. In cases of repair following tears into the rectum milk and solid food leaving much residue must be excluded from the dietary for ten days, and each bowel movement should be preceded by a high enema of six to eight ounces of sterile oil, introduced by the use of a small rectal tube and a piston syringe. Non-absorbable stitches in the perineum should be removed in nine or ten days, excepting in sphincter and rectal tears, when the lower stitches should be allowed to remain a few days longer. Stitches in the vaginal sulci should not be removed for twelve days or two weeks. The patient may leave her bed in from two to three weeks, in accordance with the firmness of cicatrization of the repaired structures.

The Intermediate Operation.—The intermediate operation is performed any time from twenty-four hours to two weeks after labor. The delay may be occasioned by any of the contraindications mentioned for the primary operation. No denudation of the tissues, as a rule, is required. The parts should be thoroughly cleansed with rough gauze sponges, and in some cases it may be necessary to scrape the parts with a knife or curet. After trimming ragged edges in order to secure good coaptation, sutures are introduced as for the primary repair.

Secondary or Plastic Operations.—The denudation operations of Emmet and Hegar, and their modifications by others, although still extensively practised, have been supplanted to a large extent by flap-splitting and resection procedures that require a certain degree of mobility of structure for their successful performance. In order to secure the most favorable results, therefore, plastic operations upon the perineum and vagina should not be attempted until the lacerated tissues have become cicatrized, the resulting cell infiltration has disappeared, and the tissues have regained their pliability. In accordance with the extent of the lacerations, local changes, and the constitutional condition of the patient, the time required to secure this state of the tissues may extend over periods varying from two weeks to two or more months.

Preparation for Operation.—The patient should be in bed at least two days before the operation. Special attention should be given to the thorough emptying of the alimentary canal. If this is neglected, the passage of hard fecal masses subsequently may bring about a separation of the sutured structures. Any one of the well-known cathartics may be given; one or two grains of calomel in broken doses, followed by Epsom salts the day preceding the operation, usually answer the purpose. In cases of obstinate constipation, especially if an operation is to be done for complete perineal tear, castor oil or salts should be given on alternate days for at least a week before operation, followed by copious flushing of the colon with the patient

in the knee-chest position. On the morning of the operation no breakfast is allowed. The external parts are shaven, the lower bowel is washed out with an enema, and a full bath is given. The final preparation of the patient and all other preliminaries incident to the operation should be carried out, as directed for the primary operation (p. 426).

Instruments.—With but few variations in their selection to meet special indications, practically the same instruments are required for all operations on the perineum and vagina. The following list is submitted, from which a selection may be made to meet the requirements of a given case: Knife; straight and curved scissors; three shepherds' crooks tenacula; two tenacula forceps; eight or ten hemostats; toothed forceps; needle-holder; rounded and sharp-edged curved needles; perforated shot; shot compressor; speculum and retractors; dressing forceps.

Suture Material.—Silk, silkworm-gut, silver wire, and catgut are the suture materials that are generally employed in plastic work. Catgut has the advantage of disintegrating after serving its purpose, and is especially adapted for buried sutures. Its comparative early absorption when exposed to the discharges of mucous membranes should be borne in mind. Dry chromic catgut is more resistant than the same catgut of equal size preserved in alcohol or other solutions. If the tissues to be sutured can be brought together without much tension, catgut may be used throughout in any of the plastic procedures. Tissues requiring more than an easy tension should be approximated with non-absorbable sutures. Of these, silkworm-gut secured with perforated shot is preferred by most surgeons.

Operation.—Four distinct surgical abnormalities, with their special pathologic sequelæ, may present themselves: (1) Incomplete perineal tear; (2) complete perineal tear involving the sphincter ani and rectum; (3) injury of the levator ani muscles and posterior colpocele or rectocele; (4) cystocele or anterior colpocele.

Two or more of these lesions may and frequently do coëxist in the same patient, but each requires special consideration from an operative standpoint in order to secure the best results. The operative procedures adapted to their repair may be classified under three heads: (1) Denudation operations; (2) flap-splitting, cleavage, and flap-formation operations; (3) resections. The full significance of these terms will become more comprehensive in the succeeding descriptions of individual operative procedures.

Operations on the Perineum.—An **incomplete tear** of the perineum causing symptoms requires denudation of the scarred area sufficient to expose and secure the retracted transversus perinei muscles and to close the gaping vulvar orifice. This is usually best accomplished by a flap-splitting procedure or by a modified Hegar resection. In either case the inner borders of the labia majora, on a level with the lowermost carunculæ myrtiformes, are caught with double tenacula and drawn apart. Beginning

upon one side, the structure to the inner side of the tenaculum is grasped with toothed forceps, and one blade of a sharp-pointed scissors is thrust into the tissues, and, by a semilunar cut, the scissors split the tissues along the existing perineal margin to the inner side of the tenaculum on the opposite side. The cut may now be deepened by blunt dissection with the fingers or with scissors to the desired depth. If the vaginal flap is to be retained, the slack in same may be disposed of by the introduction of sutures, as practised by Professor Montgomery in his operation on the pelvic floor (Fig. 134), or it may be cut away so as to leave a triangular denudation that may be closed transversely, including all the tissues or by combined buried and superficial sutures, as indicated in Fig. 125, using chromic catgut for the deep sutures, and, if preferred, interrupted silkworm-gut sutures externally.

Complete Tear of the Perineum.—Numerous methods for the repair of this lesion may be found in the various text-books, but, owing to the liability of contamination from the rectum, with resulting rectovaginal fistulæ, the complicated denudation operations formerly practised have been replaced by the simpler flap-splitting procedures, and more recently by the flap-formation methods, which practically eliminate the rent in the rectal wall as a factor in the operation. Of these, every surgeon of experience comes to adopt two or three, to which he becomes accustomed, soon learning that success depends more upon doing well the operations to which he has given most attention than upon the actual methods themselves. Whatever the operative procedure, union of the retracted ends of the severed sphincter ani muscle, with a minimum exposure of the wound to infection from the rectum, must be secured.

FIG. 125.—MODIFIED HEGAR COLPOPERINEORRHAPHY.
Deep and superficial continuous catgut sutures.

Tait's Operation for Complete Laceration.—The index and middle fingers of one hand are introduced into the rectum. One blade of a sharp-pointed scissors curved on edge is now thrust into the tissues, midway between the anus and the existing vulvar margin of the perineum, splitting the rectovaginal septum to the depth of about a half-inch. Two vertical incisions are next made, joining the transverse cut on a line with the anterior border of the larger labia, and,

extending from the level of the upper and outer caruncles to points a little outside and below the depressions or pits in the skin, indicate the position of the retracted ends of the sphincter. The combined incisions form the letter H (Fig. 126). As the vaginal and rectal flaps thus formed are held apart, a wide quadrilateral expanse of raw surface presents itself. Sutures of silkworm-gut are introduced transversely with a curved Reverdin needle. The needle is introduced about a half-inch from the cut edge of one side, passes underneath the raw surface to within a quarter of an inch of the bottom of the wound, reënters the tissues of the opposite side, and emerges through the skin on a level with the corresponding point of entrance. The lowermost suture includes the ends of the sphincter and skirts the

FIG. 126.—TAIT'S INCISIONS FOR COMPLETE LACERATION.

FIG. 127.—APPEARANCE OF SURFACE AFTER FORMATION OF FLAPS. SUTURES INTRODUCED.

rectal rent by being completely buried beneath the cut surface, excepting where it passes through the skin. Owing to the mobilization of the rectal wall, by its separation from the vagina, this suture brings the uppermost portion of the rectal tear to the level of the skin (Fig. 127). After the sutures are tied (rarely more than four are required), the sphincter ends are brought into close contact, and a deep muscular perineum is formed, separating the restored anus and the vulvar orifice. The remaining raw edge within the newly formed introitus vaginæ is closed with a continuous suture of catgut. The stitches are removed in about twelve days. In this operation there is no loss of tissue, and, if properly done, it usually gives good results. If, in addition to the rectal tear, the muscles of the pelvic floor are likewise involved, a correction of both defects may be accomplished

by carrying the incisions more or less deeply into the tissues on the sides of the rectum and vagina.

Ristine's Flap Operation.—In 1897 Ristine, of Knoxville, Tenn., introduced an operation for the repair of complete lacerations of the perineum which at once was recognized as a distinct advance over all other known procedures. It still retains its originality in principle, irrespective of its modifications by others in technic. A vaginal flap is formed by making practically a transverse cut through the vaginal mucous membrane, a half-inch or more above the rectal margin, with lateral incisions extending to the sphincter pits (Fig. 128). The flap is loosened from above downward, its attachment at the rectal margin remaining, which, upon being drawn down, covers the rectum like an apron. The sphincter ends are drawn out of their sulci with

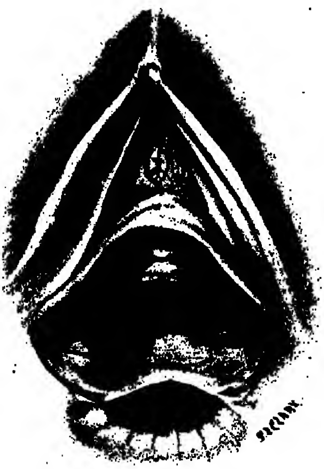

Fig. 128.—Ristine's Line of Incision for Complete Laceration of the Perineum.

Fig. 129.—Ristine's Operation. Flap turned down. Stitches introduced.

uterine tenacula or toothed forceps and sutured together. A silkworm-gut suture is now passed through both the skin and muscle. Having thus converted a complete into an incomplete tear, with the equivalent of a Hegar resection of the vagina, the balance of the wound is closed accordingly (Fig. 129). After the parts have been sutured, the flap of tissue which has been turned down projects from the anterior anal margin, and may be fastened over the line of union, thus protecting the recently united perineal tissues from fecal discharges. In this operation there is no wound involving the rectal structure, and the opportunity for the formation of a fecal fistula is reduced to a minimum.

Watkins' Operation.—Recently, Thomas J. Watkins introduced an operation that is adapted to the average case of complete laceration, and more than any other obviates the possibility of contamination from the rectum.

A straight transverse incision, about a half-inch in length, is made through the vaginal mucosa, not less than a half-inch, and in some cases an inch, above the margin of the rectal tear. A sharp-pointed straight scissors is now introduced into the incision upon one side, and pushed down to and into the retracted end of the sphincter, the location of which is indicated by the usual skin dimple. The blades of the scissors are opened so as freely to separate the tissues. The same process is repeated on the other side. The connective tissue between these two points is now thoroughly separated by blunt dissection down to the junction of the rectal wall with the existing perineal border. The end of the muscle upon either side is lifted out of its bed with a uterine tenaculum, seized with toothed forceps, and brought into view. The two ends of the muscle, including some of the surrounding connective tissue, are sutured with chromicized catgut (Fig. 130). The vaginal incision may now be closed, or, if indicated, it may be utilized as a base for the performance of a flap-splitting or resection operation upon the pelvic floor. The advantages claimed for the operation are—(1) The long distance of the external sutures from the anus, thus minimizing the danger of infection; (2) individual suture of the muscle; (3) the formation of rectovaginal fistulas is impossible; (4) postoperative enemas can be given without danger of injury or infection.

FIG. 130.—WATKINS' OPERATION. Suture of the sphincter ani muscle.

Simpson's Operation.—Simpson's operation is especially adapted to complete tears that involve the rectal wall high up. Vaginal and rectal flaps are formed as in Tait's operation. The defects in the flaps corresponding with the position of the original laceration are now closed by interrupted sutures, so as to restore the anterior rectal wall posteriorly, and the floor to the entrance of the vagina anteriorly. The knots in the rectal flap are tied in the lumen of the gut, while those in the vaginal flap face the vagina. The retracted sphincter ends and the quadrilateral raw surface are now brought together with interrupted sutures, as in the Tait operation. Individual suture of the sphincter ends and closure of the remaining subcutaneous structures with buried continuous sutures, forming superimposed layers of tissues, with separate approximation of the skin-edges, using chromic catgut throughout, have given most excellent results in my own hands.

Operations on the Pelvic Floor: Posterior Colpocele; Rectocele.—The operations for the restoration of the lost power and functions of the pelvic diaphragm following lacerations of its anterior segment are likewise indicated if these conditions depend upon diastasis of the levator muscles, the result of overdistention, subinvolution, or constitutional debility, and even if due to senile atrophy.

To Emmet belongs the credit of having devised, more than a quarter of a century ago, a surgical procedure for the correction of these abnormalities, which, with some important modifications, is still the operation of choice with many surgeons.

Emmet's operation, as modified by Dr. C. P. Noble, is well-nigh a perfect procedure in its results, but no more so than some of the

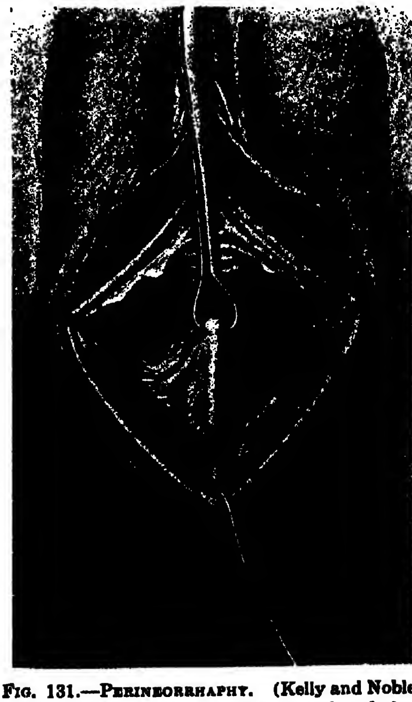

FIG. 131.—PERINEORRHAPHY. (Kelly and Noble.) The field of operation is exposed for denudation.

simpler flap-splitting, cleavage, and resection operations that are fast gaining in favor with the more advanced surgeons of our day.

Emmet's Operation, as Modified by Noble.—Two shepherds' crooks tenacula and two tenacula forceps are used to expose the field for denudation. One tenaculum forceps catches the skin of the perineum below the fourchet, on a line with the anus. The tissues in the vicinity of the remains of the hymen on each side, just below the orifice of the vulvovaginal glands, are fixed by shepherds' crooks tenacula and held by assistants. The crest of the rectocele is picked up with the other tenaculum forceps at a point which, upon the completion of the operation, will be about one-fifth of an inch within

the original position of the previously intact hymen. Owing to the variable size of the rectocele, this may be determined by lifting it up against the anterior vaginal wall, when the point to be selected should correspond with this structure just below the external urinary meatus. Traction upon these fixed points exposes three triangles—an external one, between the shepherds' crooks tenacula and the forceps attached to the skin of the perineum, and an internal one, on each side between the forceps holding the rectocele and the shepherds' crooks tenacula, and running up the vaginal sulcus a variable distance (Fig. 131). These triangular areas are now denuded by the removal of successive strips of tissue by means of toothed forceps and the

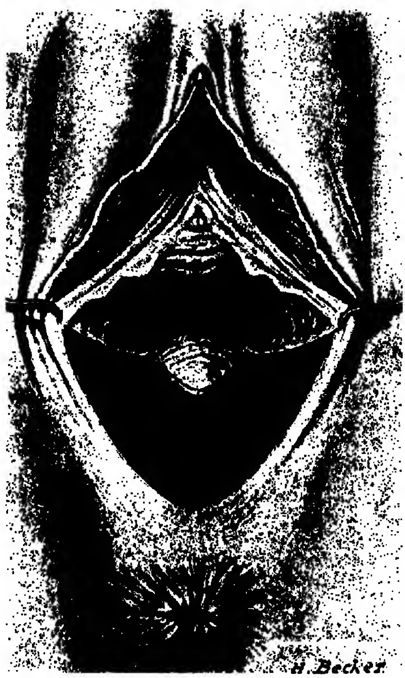

FIG. 132.—PERINEORRHAPHY. (Kelly and Noble.)
The denudation is completed.

two Emmet curved scissors, leaving a raw surface (Fig. 132). The sutures are introduced with a full-curved light-weight needle, armed with a carrier. The method of suturing is best expressed in Noble's own words: "Each suture should be tied as it is introduced. Two or three sutures usually suffice to approximate neatly the upper end of the sulcus. Usually two sutures are now introduced to attach the posterior vaginal wall to the levator ani muscle. When a rectocele exists, these sutures are employed to pick up the loose tissues of the rectocele and roll them back into the pelvis by attaching them to the levator ani muscle, at the same time elevating the posterior wall of the vagina, so that, at the completion of the operation, it shall lie

in contact with the anterior vaginal wall. The first of these sutures may be of catgut. The second should be of silkworm-gut, and act as a tension suture. When operating in the left sulcus, these sutures are introduced as follows: The lateral vaginal wall is pushed within the pelvis with two fingers of the left hand, and, at the same time, elevated toward the pubic arch. This maneuver is practised so that when the suture is passed, it will tend to fasten the lateral vaginal wall to the levator muscle at a higher plane within the pelvis. The needle is introduced 5 mm. (¼ inch) from the margin of the wound, and is passed directly through the levator muscle, so as to catch a firm hold on the muscle and its fascia. It is then brought out into the sulcus, about 1 cm. (⅜ inch) below the lateral margin of the wound. The needle is then introduced into the loose tissues of the rectocele, at a plane considerably below the point of its emergence, and made to pass along the sides of the rectocele without penetrating the rectal wall, until it emerges upon the posterior vaginal wall at a point corresponding with its point of entry. The effect of these sutures when tied is to draw the rectocele back into the pelvis and to elevate the posterior vaginal wall, and attach it to the levator muscle. The last or "tension suture" should be just within the border of the levator muscle. The location of this muscle should always be determined before placing these sutures. The denudation in the opposite sulcus is now sutured in a similar manner.

The crown suture is next passed. This should be of medium weight catgut, and is a superficial suture throughout. It is passed first through one lateral vaginal wall, the tip of the posterior vaginal wall, and then through the opposite vaginal wall. This suture is about ½ cm. (¼ inch) within the hymen, which is about opposite the anterior border of the levator muscle. The next suture should be of silkworm-gut, and its special purpose is to approximate the anterior borders of the levator muscle covered with their fascia, so as to obtain fascial union, and in this way imitate the union of the slips from the levator ani muscle, which unite in the rectovaginal septum. The needle is introduced through the lateral vaginal wall just within the hymen, and passes rather superficially from before backward and from above downward for about 1 cm. It is then made to pass deeply into the left sulcus, until the anterior border of the levator muscle is caught in the depths of the sulcus. This maneuver may be facilitated by picking up the border of the levator muscle with a dissecting forceps. The needle is then brought out of the sulcus, and is made to catch up some tissue at the bottom of the wound. It is then passed into the right sulcus deeply enough to catch the anterior border of the levator muscle, after which it is passed through the tissues of the right side in a manner corresponding to the left. When tied, this suture will approximate the anterior borders of the levator ani muscle. This procedure may be modified by burying a catgut suture to approximate the anterior borders of the levator ani muscle, or a silkworm-gut suture may be passed in the form of an 8. The next silkworm-gut

suture is introduced at the plane of the hymen to approximate the torn deep pelvic fascia. One or two deep sutures suffice to approximate the wound in the skin perineum. Silk is usually used for this purpose, as these external sutures are usually removed at the end of a week, whereas the internal ones remain for two weeks. If superficial sutures are needed, they should be of light weight (No. 1 or No. 2) catgut."

Cleavage and Resection Operations with Individual Suture of the Levator Ani Muscles.—Coincident with a true appreciation of the pathology of these abnormalities, surgeons everywhere are beginning to recognize the advisability of operating upon the faulty structures in such a way as to effect direct exposure and individual suture of the levator ani muscles, with separate closure of the overlying mucocutaneous structures, as is now generally done in approximating the torn sphincter ends in operations for complete tears of the perineum, and as practised for the closure of hernias in other portions of the body.

With the restoration of the anatomic and physiologic integrity of the anterior segment of the pelvic floor assured, the closure of the remaining portion of the wound, of whatever type, resolves itself into a mere matter of cosmetics, in disposing of redundant tissue within the vagina and of securing approximation of the vulvar structures.

The operative procedure best adapted to secure a proper cosmetic effect depends upon the proportionate redundancy of tissue in the vaginal wall itself, and upon the depth in a given case of an associated perineal laceration. In the absence of a deep perineal tear, and with moderate prolapse of the vagina, a cleavage or modified flap-splitting operation through the rectovaginal septum without any sacrifice of tissue may be indicated, but in cases with large rectocele or submucous detachment of the vaginal walls with prolapse (posterior colpocele), removal or resection of the excessively redundant vaginal structure may be done in several ways, to be referred to presently. In either case an associated perineal tear of sufficient depth to involve the transversus perinei and bulbocavernosus muscles may be corrected by an extension of the operation selected for the vagina, so as to include this structure.

Montgomery's Operation.—An operation introduced by Montgomery, founded upon the foregoing observations, which is simple in conception, easy of performance, and gives as satisfactory results as any with which I am familiar, has been practised at the Jefferson Hospital for the past five years. The technic in brief is as follows: Fixing the structures in the vicinity of the outer caruncle of one side with toothed forceps, the blade of a sharp-pointed scissors is thrust into the tissues on its inner side and the mucocutaneous junction of the existing perineal border is severed to the corresponding caruncle of the opposite side. Following this "base line of incision," the rectovaginal septum is split with scissors or blunt dissection with the fingers to a depth of an inch or more, as may be indicated; the

separation of the tissues is now carried downward and outward on both sides of the vagina and rectum toward the pelvic wall by blunt dissection with fingers only (Fig. 133), in order to expose the relaxed and retracted levator ani muscles and fascia, or until the resisting intact muscular fibers can be felt. The vaginal flap thus formed is now seized with forceps or tenaculum and held out of the way by an assistant, while the surgeon, with a well-curved needle armed with catgut, picks up the outlying levator fibers from the depth of the wound on one side (Fig. 134), passes the needle over the rectum and intervening perineal structures, and secures the corresponding portion of the muscle on the opposite side; or the muscle-fibers may be drawn into view with a hemostat or toothed forceps, and transfixed with needle and suture. Upon withdrawing the needle both muscular

FIG. 133.—"BASE-LINE INCISION" WITH CLEAVAGE OF RECTOVAGINAL SEPTUM FOR EITHER FLAP OR RESECTION OPERATIONS ON THE PELVIC FLOOR.

bundles are held in a single loop of catgut, which, upon being tied, places them into close apposition between the vagina and rectum. One or two additional sutures introduced in a like manner, one above the other, insures a wide and secure union of muscular structure. A suture is now passed transversely through the depth of the vaginal flap, immediately above the sulcus formed by the separation of the tissues, and well within the raw area. This suture, when tied, draws the tissues together and closes what otherwise would remain as a dead space upon the completion of the operation. If a rectocele existed before these maneuvers, it is now held back by a strong muscular wall, and not partially incorporated with the perineal structures, as is done in the Emmet operation, and its various modifications. In closing the superficial parts, the first suture is introduced at

the upper angle of one side of the wound, entering the skin $\frac{1}{8}$ to $\frac{1}{4}$ of an inch from the margin of the wound, passes along the free raw edge of the upturned vaginal flap, not unlike the draw-string in the mouth of a bag, the needle emerging at a point on the opposite side of the vagina corresponding with its point of entry. This is termed the crown stitch (Fig. 135), and when tied, narrows the introitus, and protects the deeper parts from contamination with the vaginal discharges. The remaining portion of the wound is closed by continuous or interrupted sutures, using whatever suture material the surgeon prefers. In this operation there is no sacrifice of tissue and a minimum of tension along the line of suture. With the hernial opening in the pelvic floor closed, the slack in the upturned flap in time retracts and accommodates itself to the anatomic necessities of the vaginal canal.

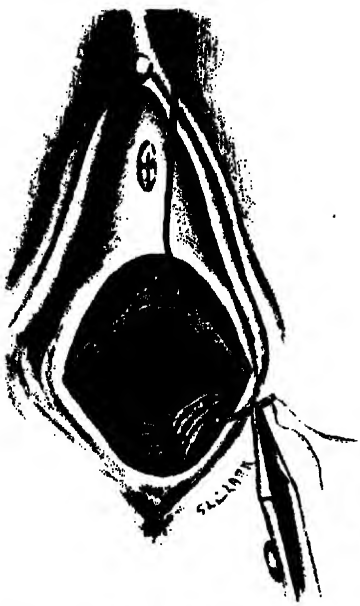

FIG. 134.—MONTGOMERY'S OPERATION.
Vaginal flap turned up. Outlying levator muscle picked up with curved needle for suture to its fellow of the opposite side.

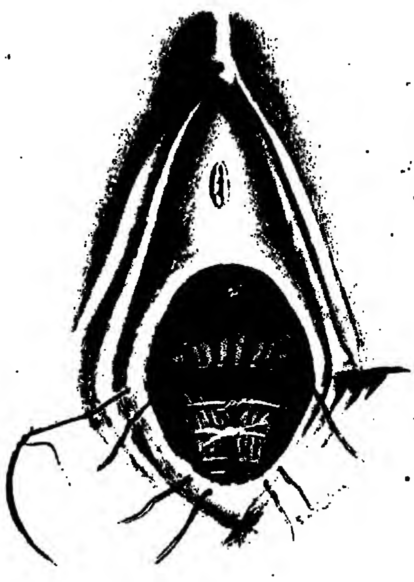

FIG. 135.—MONTGOMERY'S OPERATION.
Levator muscles sutured together. Buried suture through vaginal flap near bottom of sulcus. Crown stitch along free edge of vaginal flap.

In dealing with cases associated with redundant vaginal tissue I myself prefer to do the operation as follows: The crest of the rectocele is secured with a tenaculum forceps at a point which, when lifted up, corresponds with the external urinary meatus, and, while thus held by an assistant, the "base line incision" is made as already indicated, but in separating the septum, the median dissection is not carried up to so high a level in the vagina as practised by Dr. Montgomery. Laterally, the levators are exposed by carrying the dissection well beneath the vaginal sulci. An Emmet outline resection of the vaginal flap is now done, being careful not to remove too much tissue, because here, as elsewhere, in doing plastic work, it is always

better to err on the side of taking away too little rather than too much. The levators are now united, as in the Montgomery procedure (Fig. 136). The lateral triangles are closed with either continuous or interrupted catgut sutures. A crown stitch is now passed by transfixing the skin of one of the external angles of the resected tissues about ¼ inch from the cut edge, the denuded crest of the rectocele just under the tenaculum forceps, and the opposite external angle, the needle emerging from the skin at the corresponding point of entrance. The remaining perineal sutures are passed transversely. The sutures in the sulci, if interrupted, are tied as they are introduced, while the crown stitch and perineal sutures are not tied until all have been introduced. Care should be taken so to place the sutures that dead spaces may be avoided.

Fig. 136.—Emmet Outline Resection. Individual suture of levator ani muscle.

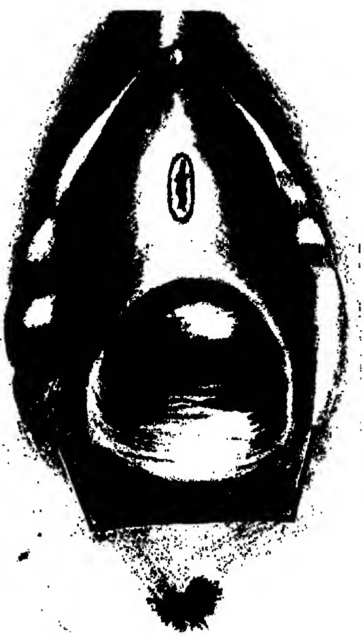

Fig. 137.—Tait's Line of Incision for Relaxed or Lacerated Pelvic Floor.

Tait's Flap-splitting Operation.—The index- and middle-fingers of one hand are introduced into the rectum. One blade of a sharp-pointed scissors curved on the edge is now thrust into the tissues, midway between the anus and the existing vulvar margin of the perineum, splitting the rectovaginal septum to the depth of a half-inch or more. It is next pushed up on either side in a curved line, ending at the anterior edge of each labium majus, at points on a line with the upper and outer caruncles (Fig. 137). Bloody oozing is usually controlled by the sutures, but spurting vessels should be ligated with catgut. The vaginal flap is held upward with tenaculum or forceps.

Sutures of silkworm-gut a half-inch apart are now introduced transversely with a Reverdin needle. The needle is introduced about ¼ inch from the cut edge of one side, passes underneath the raw surface, and emerges through the skin on a level with the corresponding point of entrance. A few intermediate sutures of catgut, and one or two to fix the free edge of the vaginal flap, may be necessary. This operation is easily and quickly performed, and if properly done in moderate relaxations of the pelvic floor without rectocele or colpocele, gives fairly good results.

Anterior Colpocele; Cystocele.—Relaxations of the anterior vaginal wall are almost invariably associated with lacerations or relaxations of the pelvic floor. The condition may be a part of a general ptosis of the pelvic structures, more especially prolapse of the uterus. Subinvolution of the tissues, depending upon lacerations and other disordered conditions of the cervix, frequently is a causative factor. General debility and senile atrophy may result in prolapse of the vesicovaginal septum, with consequent cystocele, in the absence even of other local lesions. In cases of lacerations of the pelvic floor of moderate degree the relaxed tissues may regain their muscular tone and the abnormality disappear upon restoring the anatomic integrity of the levator muscles. Usually, however, an operation upon the faulty structure itself becomes necessary.

The operative procedure adapted to the correction of an anterior colpocele, which, as already pointed out, is merely a prolapse of the anterior vaginal wall without involvement of the vesical base, is only partially applicable to the treatment of pronounced cases of cystocele in which the prolapsus involves the entire thickness of the septum. In the former, a resection of the prolapsed vaginal wall with suture generally corrects the abnormality, but to remedy the latter requires detachment of the base of the bladder from the vaginal and cervical structures, with their transposition to a higher level, and the formation of a new base of attachment, with or without a resection of the vaginal tissues. The differentiation of these two conditions in all cases before operation is not always possible, nor is this necessary, because upon separating or splitting the vesicovaginal septum (the first step in operating for either condition) the true state of the tissues is at once discovered, and the operator is then governed accordingly.

The operation for the correction of either condition is usually designated as an anterior colporrhaphy.

Anterior Colporrhaphy.—The operation is performed with the patient in the dorsal position. The anterior vaginal wall is fixed with two tenacula forceps: one held by an assistant catches the tissues a half-inch below the urinary meatus, and the other at its reflection on to the cervix, a variable distance from the external os. The latter likewise serves as a tractor by its own weight, and should, therefore, be of the heavier type of instruments. A straight incision is now made from one tenaculum forceps to the other, through the entire thickness of the vaginal wall, down to the connective-tissue layer

between it and the base of the bladder. A better plan in some cases is to pick up a transverse fold at the summit of the vaginal protrusion and cut this across with knife or scissors; the cellular layer is thus reached by a single stroke of the instrument, and with the least possible danger of wounding the bladder. The incision can then be extended to both tenacula forceps with the scissors. The bladder and the vaginal wall are now separated to the extent indicated by the size of the vaginal protrusion, upon either side of the incision, by blunt dissection or cleavage with the fingers, nicking here and there resisting bands with knife or scissors.

In cases of colpocele the cellular layer will be well developed, while the base of the bladder retains its normal position. The closer the association of the bladder with the vaginal wall, or rather the thinner the intervening connective tissue, the more the protrusion partakes of the characteristics of a cystocele. Both conditions may coexist. The vaginal walls in cases of colpocele are usually more hypertrophied and rugose than in patients with cystocele.

If the condition proves to be a colpocele, an oval resection of the vaginal flaps is done from above downward, being careful not to remove an excess of structure, resulting subsequently in undue tension along the line of suture. In order to give the vesical base additional support and minimize tension at the surface, a buried suture of chromic catgut may be used to unite the deeper portions of the wound, or this may be accomplished by the introduction of a few mattress sutures through the base of the vaginal flaps. Superficially, the wound may be closed by either interrupted or continuous sutures of chromic catgut so placed as to prevent dead spaces.

If the condition proves to be a cystocele, the vaginal flaps are held apart with hemostats, and the prolapsed vesical base is now well freed from the vagina and cervix by blunt dissection or cleavage with fingers and scissors along the line of its connective-tissue attachments to these structures (Fig. 137). The dissection may be carried up to the vesico-uterine peritoneal reflection. The risk of wounding the bladder during these manipulations is slight. The vaginal flaps are resected to the extent indicated for securing a properly retracted condition of the tissues, the broader portion of the resection being toward the cervix. The bladder-wall itself is now retracted by a purse-string suture of catgut. Approximation of the deeper tissues forming the vaginal flaps may be done with a buried suture of catgut, as already indicated. The vaginal wound should be closed from the cervix upward either with continuous or interrupted sutures; and in accordance with the original size of the cystocele and the remaining tendency to prolapse of the pelvic structures in general should the vagina be attached to a higher level on the cervix. The vaginal roof in some cases is thus lifted to the level of the internal os. This necessarily forms a more elevated base of support for the bladder, and lessens the tendency to prolapse.

Instead of resecting the vaginal flaps, these may be retained, and,

after separating and elevating the bladder, may be united by approximating their raw surfaces from base to cut edge with buried sutures of catgut, at the same time attaching the deeper vaginal tissues to the cervix as high up as may be desired. A superficial continuous suture of chromic catgut completes the operation. This leaves, as held by some, a thick column of vaginal structure as a means of additional support. The resection procedure, however, is the operation usually preferred.

FIG. 138.—OPERATION FOR CYSTOCELE.
Detachment of bladder by blunt dissection with finger. First step in Wertheim-Watkins operation.

Hemorrhage during the performance of the operation is controlled with hemostats and the subsequent suturing. Occasionally, a vessel must be ligated. The after-treatment is the same as for all plastic operations on the vagina.

Wertheim-Watkins Operation for Cystocele and Uterine Prolapse.—Wertheim and Thomas J. Watkins, working independently of each other, but directing their efforts toward the accomplishment of practically the same ends, introduced and developed an operative proce-

dure for the cure of extensive cystocele, especially in women who have passed the menopause, that is almost ideal. After separating the anterior vaginal wall from the cervix by a semilunar incision, the vesicovaginal septum is incised and split, and the bladder is detached from the vagina and uterus, as described for anterior colporrhaphy (Fig. 138). The uterovesical fold of peritoneum is now broken through or incised with scissors, and the opening enlarged sufficiently to deliver the body of the uterus. This may be done with the fingers or by traction on the fundus with a tenaculum forceps. The vesical

FIG. 139.—WERTHEIM-WATKINS OPERATION FOR CYSTOCELE.
Uterine body delivered through uterovesical peritoneal fold. Vesical peritoneal edge sutured to uterus. Sutures placed for fixation of uterus to anterior vaginal wall.

peritoneal edge may be sutured to the corresponding surface on the posterior wall of the uterus, thus closing the peritoneal opening. A suture is now passed through the vaginal flap below the urethra, through the body of the uterus posterior to the fundus, and out through the opposite vaginal flap, the needle emerging at the corresponding point of entry (Fig. 139). In placing this suture Watkins directs that care must be exercised not to draw it down so firmly that it may obstruct the urethra by pressure. A second suture is placed parallel to the first, as shown in the illustration. After these

sutures are tied, the remaining portion of the vaginal flaps is drawn over the uterine body and the wound is closed by either continuous or interrupted sutures.

Upon the completion of the operation the bladder is supported by the posterior uterine wall. The broad ligaments are shortened by

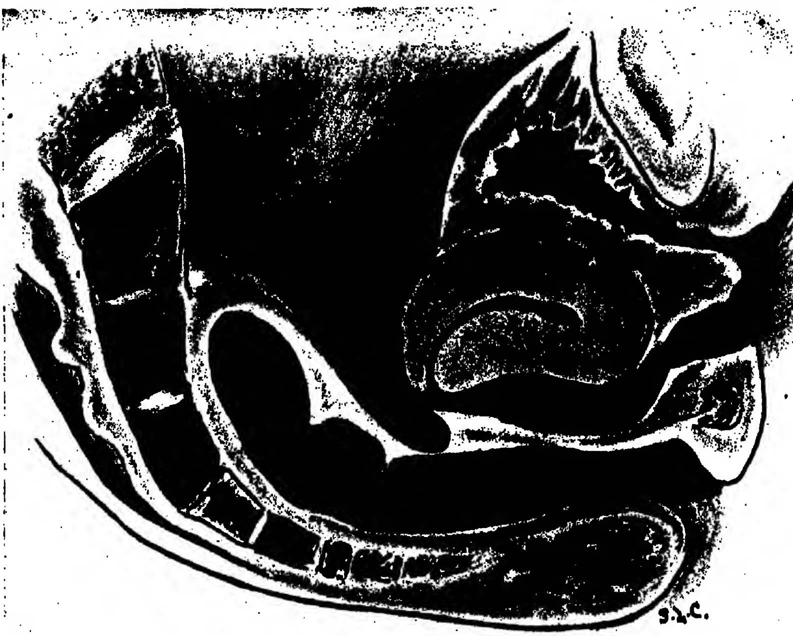

Fig. 140.—Wertheim-Watkins Operation for Cystocele Completed.

the forward tilt of the uterus, so that the organ is elevated, with the additional advantage of a changed transverse inclination of about 180 degrees, thus placing the cervix high up in the vaginal vault, at an acute angle with the vaginal canal (Fig. 140).

FISTULAS.

Fistulas peculiar to the female are openings between the urinary or the intestinal tract and some part of the genital canal.

Urinary Fistulas.—Classification.—According to their anatomic location in the urinary tract, the classification is as follows:

Urethra:
Urethrovaginal
Urethrovesicovaginal.
Bladder:
Vesicovaginal
Vesico-uterine
Vesico-uterovaginal
Vesico-ureterovaginal.
Ureter:
Ureterovaginal
Uretero-uterine.

Etiology.—Owing to improvements in midwifery and the more frequent use of the forceps, urinary fistulas the result of pressure necrosis following labor are becoming comparatively rare, and to-day more of these preternatural tracts result from gynecologic operations than from any other cause.

The relative frequency of fistulas with reference to different parts of the urinary tract has likewise changed places. Whereas formerly the bladder was the usual seat of the trouble, the extension of gynecologic procedures involving the removal of the uterus have resulted in a gradually increasing number of ureterovaginal fistulas, so that this special variety is now far more frequently met with than ever before, and occurs oftener than any other form of urinary fistulas.

Owing to the anatomic conformation of the parts, urinary fistulas involving the uterus can take place only through the cervix. Vesico-uterine fistulas usually follow obstetric operations that result in a tear of the cervix extending into the bladder, with subsequent union of the cervix below a persistent fistulous tract, between it and the bladder. Vesico-uterovaginal fistula, located at the anterior cervicovaginal junction, usually results from the same cause as the foregoing, or from pressure necrosis with destruction of the anterior cervical lip. Uretero-uterine fistulas may be regarded as a surgical curiosity.

Other causes are foreign bodies either in the vagina or bladder, ulcerating through the vesicovaginal septum, perforations incident to malignant, tuberculous, or syphilitic affections, burrowing abscesses, and very rarely gangrenous processes the result of some debilitating febrile disease, *e. g.*, typhoid fever. An opening into the bladder also may be made purposely for removing a growth or foreign body or for treating a cystitis.

Course and Symptoms.—A fistula resulting from an accidental traumatism, the use of obstetric instruments, or following a gynecologic operation is followed by an immediate discharge of urine through the vagina. In cases of pressure necrosis following a protracted labor the separation of the slough requires from four to ten days, so that the escape of urine does not occur until several days after delivery. An ulcerative perforation involving the vesicovaginal septum resulting from cancerous or tuberculous disease usually indicates an advanced stage of the morbid process, is incurable, and will not be considered further.

The course of urinary fistulas is toward ultimate closure, either primarily or by granulation and cicatrization. Clean-cut fistulas and even small fistulas, the result of necrosis involving the bladder or urethra, in some cases close spontaneously. In all other cases contraction of the fistulous tract occurs, so that upon the completion of the cicatricial process the opening may be reduced to one-half or less of its original size.

A ureteral fistula resulting from a complete division of that tubular canal never closes spontaneously, but a lateral opening in a ureter, whether clean cut, of inflammatory origin, or the result of pressure

necrosis, usually closes if given sufficient time. In a case of my own urinary leakage followed a hysterectomy with the Downes electrothermic angeiotribe. The urinary discharge, which was found to equal in quantity that passed naturally, indicated the existence of a ureteral fistula. The urinary dribbling continued for seven weeks, then gradually lessened, and finally ceased. Dr. Montgomery had a similar experience after a hysterectomy. The leakage in his case continued five weeks. A differential diagnosis between a lateral defect and complete division of a ureter can be made only by giving the fistula the test of time. If it fails to cicatrize within ten or twelve weeks, a complete division of the ureter may be taken for granted.

In cases of urinary fistula constant or irregular urinary discharge from the vagina is the most prominent symptom. Cystitis due to infection is a frequent complication, and occasionally the ureters and kidneys become involved. The infected bladder renders the urine alkaline, ammoniacal, and irritating, causing excoriations and abrasions, with resulting vaginitis and vulvitis. The vagina, especially at the site of the fistulous opening, becomes the seat of fetid phosphatic deposits. In time the patient's general health fails from loss of appetite, rest, and sleep; she becomes pale, emaciated, and in some cases cachectic. Patients with fistulas always have a disagreeable urinous odor.

Diagnosis.—Locally the conditions present are determined by touch, sight, and the use of instruments.

In *urethrovaginal fistulas* the urine is retained until it is discharged voluntarily. But with an intact pelvic floor or in the presence of obstructing cicatricial bands some of the urine may find its way to the upper portion of the vagina during micturition, and subsequently be discharged involuntarily in gushes at intervals. This may arouse a suspicion of the existence of a ureteral or vesical fistula. The proper exercise of touch and sight, aided by a Sims speculum and a probe, with the patient in the Sims position, usually clears up the diagnosis. In cases with a small fistulous opening at some distance from the meatus, if other means fail, the diagnosis may be made by exclusion by using tests for the discovery of vesical and ureteral fistula.

Vesical and Ureteral Fistulas.—If the parts are accessible, a large vesical fistula is easily recognized by touch or sight, aided, in some cases, by the use of a sound introduced through the urethra, and brought out through the fistulous opening, where it may be seen or felt with the finger. Placing the patient in the knee-chest position, and retracting the posterior vaginal wall with a Sims speculum, may bring an otherwise imperceptible fistula into view. In all cases of vesical fistulas, and especially if so situated as to permit an accumulation of urine in the bladder to be voided voluntarily, with a coincident involuntary urinary discharge more or less continuous from the vagina, and in which the existence of a ureteral fistula may be suspected, the diagnosis can be established with certainty by injecting

milk or an anilin solution into the bladder, when this may be seen issuing from the fistulous opening or from the vagina. If the fistula is very small, by first drying the vagina and then placing a piece of gauze or blotting-paper in the canal, the fluid injected into the bladder will discolor the material in the vagina at the site of the fistula. If the colored fluid in either case fails to appear as indicated, the fistula is ureteral and not vesical.

These diagnostic tests are likewise applicable in differentiating between a vesico-uterine and a uretero-uterine fistula. The diagnosis of a ureterovesicovaginal fistula is based solely upon the discovery of the ureteral orifice in the margin of the fistulous opening between the bladder and vagina.

Treatment.—*In recent cases* douches of boric-acid solution three or four times daily, keeping the urine well diluted and slightly acid, to prevent the formation of phosphatic deposits, are indicated. By observing these precautions a certain proportion of small fistulas, after two or three months, may close spontaneously, while those of a larger caliber become greatly diminished in size and are placed in the best possible condition for operation.

In chronic cases fistulas of very small caliber have closed after repeated cauterizations, using either the thermocautery or galvanocautery. Nitrate of silver and nitric acid have been used for the same purpose. This treatment at best, however, is uncertain, and operative measures to cure the condition usually become necessary. The operative treatment consists in—(1) The preparation of the patient; (2) the operation; (3) after-treatment.

Preparatory Treatment.—In some cases but little preparatory treatment, if any, is necessary; in others it may take two or more weeks to put the parts in condition for operation.

Phosphatic incrustations may be removed mechanically by sitz-baths and by douches with boric-acid solutions, and resulting raw surfaces should be painted with a solution of silver nitrate (10 grains to the ounce) once or twice weekly until healed. Reaccumulations of urinary salts should be prevented as already indicated. Cystitis, if present, must be corrected before an operation is attempted by keeping the urine slightly acid and well diluted, and by irrigating the bladder with boric-acid solution several times daily. Ordinary mutton-suet applied to the external parts is the best protective against excoriating influences of the urinary discharge, as well as for relieving existing abrasions and inflammation.

With improvements in operative methods the painful and annoying practice of a long course of treatment in stretching, dividing, and restretching adhesions and cicatricial contractures by incisions, the use of colpeurynters, and other forms of vaginal dilators has to a large extent been abandoned.

The Operation.—The preparation of the patient and the necessary preliminaries immediately preceding the operation, including the selection of instruments and suture materials, are about the same as

indicated for operations on the pelvic floor and perineum. (See pp. 426 et seq.)

Denudation Operation for the Cure of Vesicovaginal Fistula.—The classic operation for the closure of a vesicovaginal fistula of moderate size, as introduced by Sims and improved and popularized by Simon and Emmet, is performed as follows: The patient may be placed in the Sims or the dorsal position. If the dorsal position is selected, a self-retained speculum or retractors are used, as may be indicated. The cervix is seized with a tenaculum forceps and pulled down to the entrance of the vagina. The proposed limit of the denudation surrounding the fistula may now be outlined with a knife. Picking up the tissue with a toothed forceps, it is removed all around the fistula with knife or scissors, in one strip, if possible, avoiding the error of simply making a superficial denudation, but extending down to but not including the vesical mucous membrane. If the denuded surface does not appear broad enough to secure good coaptation, a second strip is removed. The width of the denudation may vary from a quarter to a half inch, in accordance with the condition of the tissues and the tension necessary to close the opening.

Small curved needles armed with carriers are used for the introduction of sutures, which may consist of silver wire or silkworm-gut. In passing the sutures, approximation of the pared edges should be effected in the direction of least resistance; the needle penetrating the tissues about a quarter of an inch from the edge of the denuded surface should be passed deeply to but not through the vesical mucosa, making its exit opposite the corresponding point of entry. Usually five sutures for each inch of approximation are necessary. None of the sutures should be tied until all have been introduced, and in doing so the tissues should be firmly approximated, but not constricted. The bladder is now washed out for the purpose of removing small clots and to test the line of union. The vagina is lightly packed with iodoform gauze, to be retained two days.

The danger of constricting a ureter in all these operations for fistula must be constantly borne in mind. If a fistula is located where a ureter might be, or the close proximity of one is suspected, the sutures should not be passed so deeply as to endanger its constriction. If the orifice of a ureter is associated with a vesicovaginal opening, the cloaca common to both is then denominated a *ureterovesicovaginal* fistula, and should be treated accordingly. Constriction of a ureter is signalized by acute pain referred to the kidney, nausea and vomiting, and diminished urinary discharge. Immediate removal of the sutures is indicated.

Hemorrhage into the bladder is another serious complication following fistula operations. The bladder may become so distended with clot as to imperil the operative field, and fatal results from this accident have been reported. In some cases the sutures must be removed to secure the bleeding point.

After-treatment.—Continuous vesical drainage with a soft-rubber

catheter is necessary for at least four days. After the removal of the instrument the bladder should be catheterized every four hours for a week. Beginning on the third day, vaginal douches with a saturated solution of boric acid should be given twice daily for two or three weeks. The bowels should be moved daily. The sutures should be removed in fourteen days.

Mobilization Operations for the Cure of Vesicovaginal Fistulas.—The value of the principle underlying the flap-splitting and cleavage procedures on the perineum and pelvic floor, and its extension to the anterior vaginal wall for the correction of colpocele and cystocele, have led to its adoption as an essential element in operations for the cure of vesicovaginal fistulas. The practical application of this prin-

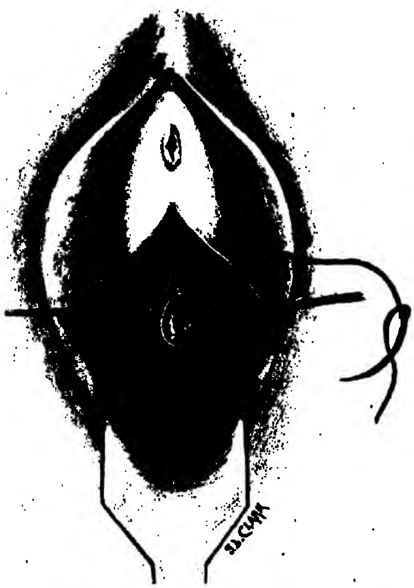

FIG. 141.—VESICOVAGINAL FISTULA.
Flap-splitting operation. Closure of fistula with buried continuous suture of catgut without penetration of vesical mucous membrane.

FIG. 142.—FISTULA CLOSED.
Approximation of vaginal flap with continuous suture of catgut.

ciple in its various forms has brought the closure of otherwise intractable fistulas of all grades, forms, and sizes, within the range of curability, and has well-nigh relegated the pioneer work of Sims, Simon, and Emmet, and the numerous complex modifications of their denudation methods, to the rear in the evolutionary development of these operative procedures. Separation of the bladder from the vagina and uterus, as first proposed and practised by A. Mackenrodt in 1894 embodies this principle. He thus secured the necessary laxity of vesical structure in the immediate vicinity of the fistula, together with the free mobility of the vesical base, to effect the firm closure of a fistulous tract of almost any size, without incurring the risk of failure from undue tension along the line of suture. In this connection it is

but just to add that all the recent contributions bearing upon this subject present nothing more than minor modifications of Mackenrodt's operation, adapted to individual cases, and have but little to do with the success of the procedure in general.

Figs. 141 and 142 (p. 451) illustrate a flap-splitting procedure for mobilizing the vesical wall in the case of a fistula of moderate size, with individual suture of the vesical and vaginal flaps with catgut, care being taken not to penetrate the vesical mucous membrane. By turning to Fig. 138 (p. 444) and to the description of anterior colporrhaphy (p. 442), the technic involved in the separation of the bladder from the vagina and the uterus and the possibility of its application to Mackenrodt's operation for vesicovaginal fistulas of large size, may be the better understood.

Mackenrodt's Operation for the Cure of Vesicovaginal Fistulas of Large Size.—The anterior vaginal wall is fixed with two tenacula forceps, one catching the cervix, and the other the tissues, a half-inch below the urinary meatus. A straight incision is now made from one tenaculum forceps to the other (if considered necessary), across the fistula, down through the entire thickness of the vaginal wall to the connective-tissue layer between it and the bladder. The margin of the fistula is split all around, separating the vagina from the bladder. This is extended well out into the tissues and upward if necessary, separating the uterus and bladder to the vesico-uterine peritoneal fold, either by dissection with knife or scissors or by cleavage. Free mobility of the vesical wall is thus secured. The edges of the opening in the bladder are denuded, if necessary, and can now be brought together without tension with continuous or interrupted sutures of fine chromic catgut, care being taken not to penetrate the vesical mucous membrane. The vaginal flaps are next denuded of scar tissue and approximated with sutures, including the forward fixation of the body of the uterus, or the uterus may be used as a base for the tissues at the site of the previously existing fistula, and to help close a possible gap between the vaginal flaps.

W. S. Stone, of New York, reports a case of *urethrovesicovaginal* fistula that illustrates the wide-spread application of Mackenrodt's ideas (to whom he gives full credit) in the evolution of all the recent operative procedures adapted to individual cases. The patient, twenty-four years old, had sustained obstetric injuries of a grave character six weeks prior to the operation. A complete laceration of the perineum was so surrounded by cicatrices that the vaginal entrance was markedly contracted, making it exceedingly difficult to inspect its upper part. The cicatricial tissue extended into the vagina in different directions. The urethra was laid open its entire length, except for a small collar at the meatus. Continuous with this opening in the urethra was one which included practically the entire septum, between the vagina and bladder. It was so large that the bladder prolapsed through the opening; its mucosa was uniformly and intensely congested. The margin of the opening was inverted

and adherent to the vaginal wall, especially as the upper border made it overlap the anterior surface of the cervix. With the patient in the Sims' position, incisions were first made in the posterior sulci of the lower part of the vagina, in order effectively to expose the field of operation. The cervix was then grasped with the vulsellum and pulled down as far as possible. The inverted and adherent vesical mucosa was dissected away from the cervix, and by making a transverse incision anterior to the cervix, as in the performance of hysterectomy, the upper part of the bladder was freed as far as the peritoneal juncture. By means of blunt dissection at the sides the entire upper portion of the bladder was thus freed, and by gradually working downward, the lower part was also separated from the edges of the fistula, care being taken not to injure the ureters, the openings of which could be readily seen. The upper and more movable part of the wall of the bladder was then brought down and sutured with interrupted chromic gut sutures to the lower and more fixed portion, the line of suture running mostly in a transverse direction, and effectually closing the bladder. The vaginal edges, although more movable than before the dissection, could not be brought into apposition without tension, but by bringing down the uterus which had been made movable by the dissection and suturing the vaginal edges to the sides and end of the cervix, the opening was closed without tension. The urethral mucosa was so thin and friable that no attempt was made to free it at the torn edge, but by an incision on either side through the vaginal wall, running parallel to and about one-half a centimeter from its edge, a flap was made which, with the aid of a more movable flap around the bladder, covered in the urethra fairly well. Interrupted sutures of black silk were used in the vaginal wall. A soft-rubber catheter was kept in the bladder for three days, and the bladder was irrigated once a day with a boric-acid solution. The entire portion over the bladder healed by primary union, but a greater part of the urethra failed to unite. There was some power of retention, however, because the vesical neck was well covered. An operation, two weeks later, in which the dissection of the vaginal wall was more extensive, effectually closed in the urethra. One month later the perineum was repaired, when the function of the bladder was normal except for a slight frequency.

After narrating a second case, Stone presented the following conclusions: "1. The basic principle in the repair of large fistulas is an extensive separation of the bladder-wall, especially of the upper part in front of the cervix, by means of which it is readily sutured to the more fixed lower portion. 2. The uterus, which has been made movable by the free dissection entailed in the separation of the bladder or by an additional incision posteriorly in some cases, is a most valuable supplement in filling up the opening in the vaginal wall. 3. With these principles applied, it is a matter of little importance what kind of suture material is used, or what relation the vesical and vaginal suture lines have to each other."

Closure of a Vesico-uterine Fistula.—Owing to the thickness of the uterine wall, this variety of fistula has a marked tendency to close spontaneously. In cases requiring operation one of four methods may be adopted:

(1) The anterior cervical lip is split to the fistulous opening, the latter is denuded of its scar tissue, and the entire wound is then closed with silver wire or silkworm-gut sutures.

(2) A transverse incision is made through the anterior vaginal fornix, as is done in vaginal hysterectomy; the bladder is separated from the cervix with knife or scissors, the dissection being carried across and well above the fistula, dividing it so as to leave a vesical and a uterine opening. The flaccid condition of the liberated vesical wall favors closure of the vesical opening with fine silver wire or catgut, without tension. After paring its edges, the uterine opening is likewise closed with catgut sutures. The operation is completed by reuniting the vaginal flap and cervix.

(3) Ready access to the fistulous tract and free mobility of the vesical wall may be secured by liberating the base of the bladder from the vagina and cervix, as indicated under Mobilization Operations for the Cure of Vesicovaginal Fistulas (p. 451) and Mackenrodt's Operation (p. 452).

(4) As a last resort in otherwise intractable cases, the fistula may be reached and closed through an abdominal incision. The uterus is drawn up with fixation forceps, the vesico-uterine fold of peritoneum is incised, and the bladder and cervix separated by blunt dissection and with knife and scissors, passing through the fistula, thus forming a vesical and a uterine opening. After securing an aseptic field free from cicatricial tissue, both fistulous openings are closed with catgut sutures. The vesico-uterine peritoneum is now reunited over the field of operation, and the abdomen is closed. A better plan, and one adapted to the cure of *vesico-uterovaginal fistulas* as well, is to carry the separation of the structures between the bladder and uterus through the fistula into the vagina. After suturing the vesical and uterine openings, a strip of iodoform gauze is introduced into the vagina from above, and packed between the uterus and bladder. The peritoneum is now drawn over the gauze and field of operation, as previously indicated, and the abdomen is closed. In cases complicated by serious supravaginal disease with fixation of structure, in order to secure a proper exposure of the vesical opening for successful suturing, a complete hysterectomy may be necessary. After removing the uterus and appendages and closing the fistula, gauze is lightly packed between the bladder and the rectum. A running suture of catgut unites the peritoneum covering the rectum with that of the bladder and the remaining upper borders of the broad ligaments in such a manner as to turn all stumps and raw surfaces toward the vagina, thus completely separating the field of operation from the peritoneal cavity. The abdomen is now closed. In either case the gauze packing is removed from the vagina in four or five days, after

which a boric-acid douche is given twice daily for a period of two or more weeks.

Closure of a Vesico-uterovaginal Fistula.—Fistulas of this variety present great variations in size, some barely admitting a uterine sound, while others may involve not only the cervix, but the greater portion of the vesicovaginal septum as well. A small fistula may close spontaneously, or complete closure may follow repeated applications of nitrate of silver, but usually operative interference becomes necessary. Surgically, a fistula of this type may be closed in one of four ways:

(1) In the case of a small fistula of recent origin and without much scar tissue, a funnel-shaped denudation at the expense of the vaginal structure may be made, followed by closure of the wound with sutures.

(2) The anterior cervical lip may be utilized to close a comparatively large fistula by denuding its edges, continuous with a corresponding denudation of the edges of the fistula on the vaginal side. The raw surfaces are now approximated with sutures as usual. Before tying the sutures, to minimize tension along the line of union it may become necessary to split the cervix bilaterally to secure elongation and mobility of its anterior segment. In cases with extensive destruction of the anterior lip of the cervix, the posterior lip may be denuded and sutured to a vaginal denudation of the fistula, thus turning the cervical outlet, with subsequent discharges, from the uterine cavity into the bladder. For obvious reasons the latter procedure is not to be commended.

(3) The uterus and bladder are separated by a transverse incision through the anterior vaginal fornix, as indicated for vesico-uterine fistula. The edges of the fistula are now denuded, the opening closed with catgut, and the vaginal vault restored by reattaching the vaginal flap to the cervix.

(4) See Closure of a Vesico-uterine Fistula (3 and 4, above).

Closure of a Ureterovesicovaginal Fistula.—One of several plans may be adopted: (1) Make an oval denudation, one-quarter to one-third of an inch wide, around a portion of undenuded mucous membrane, the center of which is occupied by the fistula. The denuded surfaces are now united by sutures, thus turning the ureteral orifice into the bladder. (2) Locate the ureteral orifice, then split the ureter on the vesical side to the extent of a half-inch, allowing the edges to heal separately, so as to place the orifice further back into the bladder. This may likewise be accomplished by Dudley's clamp operation (p. 456). Either of these procedures eliminates the ureteral orifice as a complication of the fistulous opening, and reduces the condition to a vesicovaginal fistula that may be treated accordingly (p. 449).

Closure of a Ureterovaginal Fistula.—The tedious and uncertain plan of first dissecting the ureter out of the scar tissue and then implanting it into the bladder has been superseded by more expeditious and better methods. It is still generally held, however, that

in operations for the cure of this variety of fistula the ureteral opening must first be located so that its communication with the bladder may be successfully reëstablished. Most surgeons of the present day advocate, as a first step, a colpocystotomy at or near the ureteral opening, *i. e.*, the conversion of a ureterovaginal fistula into a uretero-vesicovaginal fistula, and then treating the resulting condition as though it had existed originally.

In *Schede's operation* the vesical fistula is made near the ureteral orifice, the vaginal and vesical mucous membranes along its edges being united by sutures. A denudation is now made, encircling both fistulous openings, and this is united so that the fistulous tracts, surrounded by an island of the vaginal mucous membrane, are turned into the bladder.

Dudley's clamp operation is especially adapted to cases where the distance and the amount of tissue between the bladder and ureter are so great that its division with knife or scissors would entail the risk of uncontrollable hemorrhage or excessive cicatricial contraction. These objections are met by clamping the ureter into close contact with the bladder. The operation is performed as follows: The ureteral orifice is located, a colpocystotomy is now done, so as to include, if possible, the ureteral opening in the incision, and thus create a *ureterovesicovaginal* fistula. In order to control hemorrhage, the bladder and vaginal mucous membranes bordering the fistula thus created are united by sutures. A long hemostat with slender blades is next passed through the vesicovaginal fistula, one blade entering the ureter and the other the bladder. The forceps, upon being locked, includes the bladder-wall, the ureter wall, and the intervening connective tissue. The hemostat becomes detached by pressure necrosis in three or four days, leaving a ureterovesical opening at some distance from the existing vesicovaginal fistula, which is closed later.

Closure of a Ureterovaginal Fistula Following Hysterectomy.—For obvious reasons, locating a ureterovaginal fistula is not an easy task, as a rule, and the search for the ureteral orifice may consume more time than the operation for its closure after it has been found. In an operation witnessed recently for the cure of a ureterovaginal fistula following a complete hysterectomy the exact position of the ureteral opening was neither located nor was it even looked for. That the fistula was situated somewhere in the cicatrix was taken for granted. The operation was performed by Dr. E. E. Montgomery as follows: The scar was encircled by an incision a half-inch below the summit of the vaginal vault. A peripheral flap following the line of this incision was now dissected down about a half-inch in width. Guided by a Pratt's bougie introduced through the urethra, the vesical wall was pushed into the raw surface bordering the undenuded central area anteriorly, and was then incised transversely to the extent of a half to three-quarters of an inch. The edge of the anterior vesical flap was drawn into view with a hemostat. Chromic catgut

sutures were now introduced into the flap from below upward, carefully avoiding penetration of the vesical mucous membrane. These same sutures were then carried from above downward through the denuded surface on the posterior wall of the vagina, so that, when tied, the vesical mucous membrane was continuous with the undenuded central area, thus making the latter, with the ureteral opening, a part of the interior of the bladder. Especial care was exercised in closing the angles of the opening. After testing the line of suture by vesical distention with sterile salt solution, the vaginal flaps were united transversely with a continuous chromic catgut suture. Hemorrhage during the operation was controlled by repeatedly infiltrating the tissues with adrenalin solution 1: 3000. Upon the completion of the operation a self-retaining soft catheter was introduced. This was removed in three days, after which the patient was catheterized every four hours for a week longer. The patient made an uninterrupted recovery, and was one of three other cases of a similar character upon whom the same type of operation had been successfully performed within a period of two years.

Kolpocleisis.—The only operative alternative for cases of otherwise intractable *vesicovaginal fistulas* is closure of the vagina. Kolpocleisis is performed by removing a wide strip of tissue from the circumference of the vulvovaginal outlet, and uniting the denuded surfaces with interrupted sutures. This converts the bladder and vagina into a common cavity for the urine, menstrual blood, and other uterine secretions, to be discharged at intervals from the urethra. Owing to the stagnation and infection of accumulated discharges and the tendency to the formation of inaccessible calculi, resulting in complications far more seriuos than the original condition, this operation has been and still is generally condemned by surgeons. While the deliberate removal of the urethra and the establishment of a rectovaginal fistula combined with closure of the vaginal orifice in these cases may be objectionable on theoretic grounds, its practical value following an operation of necessity, has been demonstrated in the following case: In 1873 (thirty-six years ago) Mrs. D., then thirty-five years old, came under the care of Dr. W. W. Keen. She had two large vesical openings (separated by a slight bridge of tissue) involving the posterior part of the urethra, the floor of the bladder up to the uterus, and one rectal opening an inch in diameter, one and a half inches above the anus, all the result of gangrene and sloughing incident to a severe attack of typhoid fever. Within a period of two years and nine months fourteen unsuccessful attempts were made by Drs. Grove and Keen to close the fistulous tracts, but at the fifteenth operation (1876) Dr. Keen gave up the attempt, excised the urethra, and closed the entire vulvar aperture. The operation proved a complete success. Subsequently, she necessarily menstruated, defecated, and micturated entirely by the rectum. She has rarely been obliged to empty the rectum oftener than twice at night and five or six times during the day. She passed the meno-

pause eleven years after the closure of the vagina. Her subsequent history was briefly summed up by Dr. Keen in 1898 in his work on "The Surgical Complications of Typhoid Fever" in these words: "It is an encouraging fact that in any case requiring similar treatment the later history shows that for twenty-one years she has only twice had the least trouble, once from a small calculus forming in the vagina, and once from a small abscess forming in the cicatrix, which abscess spontaneously closed. Instead of being a constant source of disgust to herself and everybody about her, a hospital patient dependent upon charity, and a Pariah cut off from all society, she has been enabled to become self-supporting as a nurse, and to enter freely into her wonted social relations." This patient was admitted to the Jefferson Hospital March 9, 1909, complaining that during the previous two months she had suffered from an occasional slight leakage of urine. A fistulous opening hardly larger than a pin-point near the center of the vulvar cicatrix was discovered. A small abscess developed near this, and discharged through the opening. Two weeks later the parts were almost completely cicatrized, but there is still a small fistulous opening that may require surgical attention. With the exception of a similar experience a few years ago at which the fistulous tract had to be closed by operation, she has suffered no annoyances of rectum, bladder, or vagina during *thirty-three years.* The recto-vaginal opening still admits the tip of the finger.

Fecal Fistulas.—Fecal fistulas peculiar to the female are openings between some part of the intestinal tract and the genital canal.

Classification.—1. Rectovaginal. 2. Rectoperineal. 3. Entero-vaginal.

Etiology.—A *rectovaginal* fistula is an opening between the vagina and rectum. The lesion is most frequently caused by malignant or syphilitic ulceration, but in rare instances may be due to obstetric or accidental traumatisms, or to pressure necrosis of a retained foreign body. *Rectoperineal* fistulas are abnormal openings that begin in the rectum and open on the surface of the perineum. They usually result from an imperfect union of the tissues after an operation for the repair of a complete laceration of the perineum and recto-vaginal septum. A fistulous tract connecting the rectum and one of the labia generally is caused by burrowing abscess formations. In *enterovaginal* fistulas some part of the small intestine communicates with the vault of the vagina, generally the result of a suppurative process within the lower portion of the peritoneal cavity, or following pelvic operations (with vaginal drainage) involving the small intestine, either accidentally or otherwise.

Diagnosis.—Discharges of fecal material and the escape of gas are characteristic symptoms of all fecal fistulas. A rectovaginal fistula may vary in size from an opening admitting a small probe to that of one involving the loss of a large portion of the rectovaginal septum. It may be located by touch or sight, aided by the use of a speculum, a probe, or by injecting a colored fluid into the rectum, when this

will be detected escaping into the vagina through the fistulous tract. The direction of a rectoperineal fistula may be determined by the use of a probe. An enterovaginal fistula is usually diagnosed from the history of the case and its location in the vault of the vagina.

Prognosis.—A rectovaginal fistula of cancerous origin is incurable. An operation upon a fistula, the result of syphilitic or tuberculous ulceration, generally fails unless preceded by appropriate constitutional treatment. Fistulas following pressure necrosis, inflammatory processes, or those resulting from previous pelvic operations or operations on the perineum usually result favorably after proper surgical measures.

Treatment.—The preparation of the patient is the same as for operations on the perineum for complete lacerations (pp. 426, 427). In all cases after the patient has been anesthetized the sphincter ani muscle should be thoroughly stretched. The same general principles underlying operations for the cure of vesicovaginal fistulas are likewise applicable to the treatment of rectovaginal fistulas (p. 449 et seq.). In denudation operations the dissection must always be made at the expense of the vaginal tissues. In order to secure proper mobilization of structure, the rectovaginal septum may be split as in operations for urinary fistulas. Firm coaptation without tension with sutures introduced so as to extend to, but not through, the rectal mucosa is the secret of success in all these operations. A rectoperineal fistula usually requires complete division of the perineum through the sphincter ani, following the course of the fistula to its termination in the rectum, with resection of the fistulous tract and subsequent closure of the wound, as indicated for recent cases of complete laceration of the perineum. An enterovaginal fistula may be treated by cauterization or by denudation and suture. Usually its closure through an abdominal operation becomes necessary. The after-treatment in all these cases is the same as for operations on complete lacerations of the perineum.

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SURGERY OF THE UTERUS, BROAD LIGAMENTS, AND FALLOPIAN TUBES.

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Inflammation of the Uterus.—Any portion of the uterus may be the seat of inflammation. The process may predominate in the cervix or in the body; it may be confined to the lining membrane, or extend to the parenchymatous tissue and even to the enveloping structure—the peritoneum.

In the effort to designate the various forms of inflammation, classifications have been based on the etiology, the clinical phenomena, and the pathologic changes.

From the etiologic side, the proper division would seem to be into the conditions which result from the action of microörganisms and those disorders independent of their influence. Unfortunately, our knowledge of the ultimate influence of the microörganisms is insufficient to enable us to definitely define their relation to the existing inflammatory process, nor, on the other hand, can it be asserted that inflammation of the uterus ever exists absolutely independent of bacterial origin.

In the present state of our knowledge I prefer to make the classification from the pathologic changes, as affording the nearest approximation to a definite basis. This classification comprises a division

into acute and chronic inflammation, and the latter is subdivided into endocervicitis, endometritis, and metritis. Chronic endometritis is still further divided into the glandular, interstitial, and mixed varieties. Acute endometritis involves both the body and the cervix.

Acute inflammation of the uterus is not confined to the endometrium, but rapidly extends to the entire organ. It may occur in either the puerperal or the non-puerperal uterus, though much less frequent and severe in the latter. In all cases acute inflammation is the result of infection. In the non-puerperal cases it is induced by gonorrhea or is the result of trauma from exploratory operative procedures, and occasionally is an exacerbation of a chronic condition.

The acute condition is most frequently the result of infection incident to the evacuation of the contents of the pregnant uterus, either at term or during the course of gestation. The infection is promoted by prolonged labor, during which the tissues undergo extensive bruising or laceration; by want of skill and cleanliness in the employment of manual and instrumental procedures; by the retention of clots, portions of placenta or decidua following labor or abortion; by the existence of septic germs in the genital canal prior to the delivery, or by their introduction during its progress or during convalescence.

The original site of the infection is the degenerated mucosa, the clots plugging the uterine sinuses, the former situation of the placenta and retained portions of the placenta and decidua. The structures become greatly swollen, with alterations in all the tissue elements. The glands are distended by increased secretion and the proliferation of their epithelium. Round-cell infiltration with subsequent degeneration and destruction of the cell elements occurs. The blood-vessels become engorged and thrombosed, and the inflammatory invasion may terminate in abscess formations in either the wall or the sinuses or both. The collections of pus, at first localized and small, increase in size, break down the intervening partitions, and form large abscesses, frequently causing the destruction of the greater part of the affected organ. The virulence of the condition and the gravity of the case will depend on the character of the infection. The principal forms are the saprophytic, the gonorrheal, and the septic. The former is associated with the retention of blood-clots or portions of the placenta or the decidua which undergo putrefaction, with the subsequent absorption of the toxins, the products of decomposition. The septic process is much more frequent, and generally engenders a primary disorder by the entrance of the pathogenic germs through fracture of the uterus, cervix, vagina, or vulva. Not infrequently it may be superimposed on the saprophytic invasion. A previously existing gonorrhea may be the cause of a fulminating inflammation which may be difficult to differentiate from septicemia, and may afford the favorable soil for the development of a virulent attack of the latter.

Symptoms and Signs.—The infection from saprophytes develops in from three or four to ten days following delivery, and is rather sudden in its onset, with a marked elevation of temperature and repeated chills. The temperature varies from 102° to 105° F.; I have seen it 106° F. The lochia is either absent or excessively offensive. Manipulation over the uterus may cause expulsion of a large offensive clot, following which the patient will improve, or she may have profuse bleeding. Digital exploration of the cavity of the uterus in such conditions reveals the presence of decomposing masses, and discloses evidence of their decomposition. The septic process develops more insidiously and occurs earlier. The symptoms induced by septicemia will depend on the condition of the patient, the character and virulence of the infection, and the time of its introduction. Very shortly, or within two or three days, after the delivery, the patient will betray an elevation of temperature which will gradually increase with morning and evening variations Pain and tenderness in the lower abdomen are recognized and may become so marked as to confine her to the dorsal position, with the limbs drawn up. The bladder will frequently become greatly distended. The pulse is rapid—from 110 to 140—and wiry, the respirations frequent, and the temperature may vary from 101° to 107° F. When the parenchyma of the uterus is the seat of the disease, that organ is large, boggy, swollen, and somewhat tender, but will permit of careful palpation; but when the peritoneum becomes involved, the patient is sensitive, even to the pressure of the bed-clothes, and will resent the most careful palpation. The lochia may be suppressed, thin, and watery, or very profuse and sanguinopurulent. The discharge may be free from odor or have a stale, sickening smell. The cervix, vagina, and the external genitalia may appear normal or swollen, covered with a diphtheric exudate or with thick, glairy mucus. Lacerations of all these parts may present avenues for the entrance of the infection. The cervix may be lacerated and enlarged, the entire uterus swollen, edematous, and tender to pressure.

The progress of the disease will depend on the virulence of the poison and the resistance of the patient. In some the disease becomes localized as an abscess in the wall of the uterus, the tube, or the ovary; in others the infection rapidly passes into the circulation, producing systemic infection. A persistent high temperature, a pulse-rate continually above 130, and the absence of focalization may be regarded as presenting an unfavorable prognosis. Even should the serious symptoms subside and the condition of the patient apparently improve, while the pulse-rate persists at or above 130 the patient cannot be regarded as out of danger. The infective process, which has had its origin in the uterus, may extend to the tubes, the ovaries, the pelvic peritoneum, the peri-uterine cellular tissue, or to any of the veins, producing a septic phlebitis, known as milk-leg, when the femoral or saphenous veins are the vessels involved. The infection may invade the lymphatics, becoming a lymphangitis.

Diagnosis.—The early recognition of the form of the infection is of the greatest importance. The sudden development of grave symptoms after delivery in a patient who was apparently doing well, associated with the presence of offensive lochia, is presumptive evidence of saprophytic infection, which is confirmed by the digital discovery of decomposing clots or portions of placenta or decidua. The rapid improvement of the symptoms, with the removal of the offensive material, makes an absolute demonstration. With septicemia the onset is more insidious, and occurs at an earlier date, unless the implantation of the infection takes place late. An elevated temperature following labor or abortion should be regarded as a danger-signal demanding careful investigation. The condition of the breasts should receive consideration. The possibility of typhoid or malarial infection should be eliminated by blood examinations, and the presence of other toxic conditions should be excluded. When any complication of the puerperium was regarded under the generic term of "puerperal fever," the attendant was spared much exertion in differentiating the condition, but with our present advantages he must know the infection with which he is dealing, and thus be the better prepared to meet the foe. The course above indicated permits him to reach the diagnosis of septicemia by exclusion, but it is still important that he should recognize the earliest manifestations of localization. A large, boggy, more or less swollen uterus indicates the presence of metritis; perimetritis or pelvic peritonitis will cause marked tenderness over the surface of the uterus and the lower abdomen. The patient will suffer severe pain, present an expression of anxiety, have a very frequent, wiry pulse, a high, sometimes low, and occasionally even a subnormal, temperature, the latter being a symptom of great danger. Phlebitis will be indicated by pain over the veins affected—generally, the femoral and saphenous. Lymphatic involvement is generally associated with inflammation of the cellular tissue,—pelvic cellulitis or parametritis,—and is frequently indicated by pain and tenderness over the inguinal and lumbar regions. Not infrequently septicemia undergoes a rapidly fatal course, without apparent or perceptible local manifestations.

Prognosis.—The saprophytic infection affords the most favorable outlook, but it should not be forgotten that it also presents a favorable soil for the introduction of the more dangerous pathogenic micro-organisms. When uncontaminated, the removal of the putrid products is quickly followed by a subsidence of all the grave symptoms and rapid convalescence of the patient. Septic infection is the gravest of disorders, fraught with danger to life, and when the patient escapes, it is often with her organs crippled as to subsequent function, or so diseased as to require their future sacrifice.

Treatment.—The most effective treatment is the prophylactic; hence the nearer the accurate methods of the surgeon can be imitated in the management of the obstetric patient, the less the danger. Variations from the normal course of the puerperium should demand

immediate investigation as to the cause, the removal of any decomposing products from the genital canal, with careful cleansing of the affected surfaces and the employment of measures to maintain subsequent drainage. These are the cases in which the curette and packing the cavity with iodoform gauze will be efficient. In septicemia, on the contrary, the disease is so far advanced when the attendant awakes to its importance that the employment of the curette is of doubtful expediency. The infection has already passed beyond the superficial structures affected by the curette, and it is better to secure absolute rest, regulate the bowels, give a generous, readily digested diet, maintain cleanliness, promote elimination, and watch for local manifestations. The external application of the ice-bag and the continuous slow irrigation of the rectum are two measures always worthy of consideration. Early involvement of the peritoneum should be met by curetting, cleansing, and packing the uterus, and an incision through the posterior vaginal fornix, which should be drained with iodoform gauze, and the patient placed in the Fowler position (Vol. III, p. 707), with the Murphy treatment of continuous rectal irrigation (Vol. III, p. 775). Collections of pus, when accessible, should be evacuated through the vagina, as nature's barriers are thus regarded, and the danger of the spread of infection lessened. The recognition of purulent destruction of the uterine walls should be considered an indication for hysterectomy. The retention of such an organ is fraught with danger.

FIG. 143.—EROSION WITH PAPILLARY HYPERTROPHY.

Endocervicitis (Chronic Cervical Catarrh).—Endometritis of the cervix affects not only the canal, but the entire structure below the internal os. The character of the disease varies greatly in the unmarried or the nulliparous and the woman who has borne children. In the former, decided small-cell infiltration occurs, the capillaries become dilated, sometimes to such an extent as to resemble hemorrhoids. The squamous cell epithelium often becomes infiltrated with leukocytes and undergoes hypertrophy from the increased blood-supply. The papillæ become enlarged, are covered with a single layer of epithelium, which permits the red color to be displayed and gives the appearance of an erosion. This is generally regarded as a simple erosion, and is usually confined to the squamous epithelium of the cervix. In the multiparous, the cervix has undergone more or less laceration, which often permits the lips to be widely separated. The mucous membrane is everted, and presents an irregular granular appearance, which extends beyond the os. This condition was formerly regarded as ulceration, but microscopic examination dis-

closes the apparently denuded surface, covered with epithelium. The continually engorged condition leads to eversion of the mucous membrane, eventually to obstruction of the glands of the cervix, and an accumulation of their secretion within well-defined cysts. The cystic degeneration of a large number of the glands causes the cervix to be apparently made of cysts which penetrate its entire structure (Fig. 144). Such cysts are known as retention cysts, or ovules of Naboth. They may encircle the external os, or may have pushed into the structure of the cervix at some distance from the os.

FIG. 144.—EXTENSIVE CYSTIC DEGENERATION OF THE CERVIX. (Montgomery.)
a, Glands dilated with secretion; *b*, large nodule formed by union of many glands and distended with fluid.

They are generally filled with the secretion of the glands, but may become infected and form small abscesses. The increased glandular secretion and the transudation from the denuded surface cause a very profuse leukorrheal discharge. Not infrequently a hyperplasia of the cervix occurs, which greatly increases its size. In the nulliparous the cervix forms a rounded mass, and hence becomes enlarged in every direction, or it may become so elongated as to resemble prolapsus, and is known as pseudoprolapsus. Where a cervix has been previously lacerated, this hyperplasia causes the lips to be widely everted and to become fixed. The surface is covered with distended cysts,

recognized as pea-like masses under the finger. They form abscesses or rupture, and, with the proliferating epithelium, present a raw surface often difficult to differentiate from epithelioma of the cervix. A large cyst may be formed by the absorption of the intervening walls when the cysts are in close relation. Puncture of a cyst permits the discharge of a thick, viscid fluid, rich in corpuscles. Endocervicitis is the result of extension of inflammation by way of the body of the organ, the vagina, or the vulva. The provoking causes are excessive coition, lacerations, injuries from instrumental and digital examination and from gonorrheal and septic infection.

Symptoms and Signs.—Leukorrhea, pain in the back and down the legs, increased on standing and walking, irregular menstruation, and sterility are the principal symptoms, of which leukorrhea is the most important. The discharge from the glands is thick, viscid, and transparent, white when mixed with mucus-corpuscles, and yellowish from pus-corpuscles. It is sometimes tinged with blood. Menstruation is generally irregular, the quantity of the flow being increased. Sterility is frequently observed. In the childless woman the cervix is puffy and large, the os soft and velvety and eroded or hard, covered with pea-like nodules, polypoid projections, or cystic masses. The os may be gaping, allowing the finger to penetrate nearly to the internal os. The lips may vary in size, the one having undergone involution, the other hyperplasia. The conditions recognized by the digital examination can be observed also by the employment of the speculum. The Sims speculum is preferable, as it causes less displacement and permits of more thorough inspection. The nulliparous os will be filled with a plug of tenacious mucus and present a patch, especially over the posterior lip, of excoriated tissue which has lost its superficial layers of epithelium. The multiparous cervix is frequently lacerated, and the angles of the tear often so filled with indurated, cicatricial tissue that the lesion escapes the observation of the careless observer.

Diagnosis.—A plug of mucus so viscid and tenacious that it can be removed with difficulty fills the cervical canal when exposed with the speculum, and differentiates endocervicitis from vaginitis. The distended glands can be evacuated by puncture. The differentiation from endometritis is often especially uncertain; indeed, it may be difficult to say that the two conditions do not always coexist to a greater or less degree. The enlarged, thickened, and indurated cervix would indicate it as the seat of the disease. The glandular degeneration of the cervix is sometimes regarded as carcinoma, but the absence of infiltration and the more general and uniform hypertrophy, the greater consistency, and the absence of friability are sufficient to render the diagnosis certain. In malignant disease the cervix is hard in points as a result of the localized infiltrate. As the disease advances the hardened surface presents an excavated ulcer with infiltrated edges. The tissue will be friable and easily broken down, while the base will be firm and hard. When there is any doubt as to the diag-

nosis, a test excision should be made and the excised tissue subjected to microscopic examination.

Treatment.—The most important consideration from the surgical standpoint is to establish ample drainage. Where the os is small or pin-hole in size, not infrequently the cervical cavity will be found distended and full of thick, viscid mucus. The dilatation or stretching of such an os will be followed by recontraction. The better procedure is to incise it crucially and remove the intervening flaps, after which the mucous membrane lining the canal is sutured to that of the portio vaginalis. Distended Nabothian follicles should be punctured, and the cavities painted with tincture of iodin, or a solution of iodin crystals in carbolic acid. A lacerated cervix with everted and thickened mucosa calls for amputation, and the preferable procedure is the single-flap operation of Schröder (p. 478).

Chronic endometritis is applied to an inflammation of the lining membrane of the body of the uterus. Ruge divides it into the glandular, interstitial, and mixed, according to the portion of the mucous membrane affected. In each variety the entire structure of the membrane is more or less affected. As the membrane becomes thickened, the glands become elongated, bent, tortuous, and dilated, the cell structure swollen and proliferated, and resembles the decidua. The vessels are dilated and distended. The mucous membrane is frequently several times its normal thickness. In some the membrane is full of the distended glands; in others, of distended blood-vessels, and a third variety in which there is a large amount of embryonic tissue, but few vessels and scarcely a trace of glands. With the conditions mentioned there are three kinds of discharge—the leukorrheal, the sanguinolent, and the mucopurulent. Portions may project as polypoid masses of glandular or vascular tissue from the surface of the membrane. In some cases the hyperplasia of the mucosa results in the exfoliation of the surface of the membrane, either in shreds or as a more or less exact cast of the cavity of the uterus. The condition is known as endometritis exfoliativa, or membranous dysmenorrhea; better, perhaps, as menstrual decidua.

Symptoms.—Endometritis follows abortion or labor as the result of a mild infection, and not infrequently gonorrhea in the non-puerperal. It occurs more frequently in the multiparous, and is more common in the later days of the menstrual life. The nulliparous are not exempt, and it may occur in the virgin, when it is known as virginal endometritis. This is generally associated with stenosis or narrowing of the external os. An accumulation of secretion which often decomposes and becomes exceedingly offensive is not infrequently seen in women late in life, several years after the climacteric, and is known as senile endometritis. This collection is not infrequently discharged into the vagina, and, from its extremely offensive odor, is often regarded as evidence of the presence of cancer in the body of the uterus. The characteristic symptoms of endometritis are leukorrhea and menorrhagia. The discharge from the body is

thin and watery, and much less tenacious than that from the cervix. The character of the discharge will depend on the variety of the inflammation present. In the glandular it is thin and clear, or white from desquamated epithelium, yellow from admixture of pus-cells, or tinged with blood. In the interstitial variety the discharge is slight, often so tinged with blood that the patient imagines herself continuously sick, and the menstrual flow is apt to be prolonged and extremely profuse, frequently amounting to hemorrhage. In the mixed form, both the hemorrhage and the leukorrhea are marked symptoms. In all forms the discharge may be more or less continuous, or may be retained and then be discharged in quantity. This symptom characterizes the cases complicated by retrodisplacements of the uterus, or those in which the canal is contracted, and the organ has to go into labor to evacuate its contents. Dysmenorrhea is not a constant symptom of endometritis, except in cases with narrowed canal, or where there is a desquamation of the epithelium as a more or less well-marked cast of the uterine cavity. That the existence of endometritis is a hindrance to conception is evident from the frequency with which pregnancy occurs after the organ is curetted. Its existence prevents the proper preparation of the endometrium for the reception and nutrition of the fecundated ovum, hence the greater frequency of abortion.

Diagnosis.—The more or less continuous leukorrhea, the prolonged menstruation, and the enlarged uterus following a history of abortion or prolonged convalescence after labor render the diagnosis certain. The examination of the curetted tissue is of great value. It exhibits marked small-cell infiltration, with absence of glandular hyperplasia, or extensive glandular hyperplasia with proliferation of the glandular epithelium. The cells of the epithelium lose their original cylindric shape, become granular and enlarged, and resemble the decidua cells. The long-continued irritation of the disease predisposes to the development of malignant degeneration. The senile form, with its offensive discharge, is frequently mistaken for carcinoma, but a careful examination reveals perfectly smooth walls, with no sign of infiltration. Where the treatment of the condition is neglected, the inflammation penetrates to the subjacent layers, causing metritis, or may involve the tubes, causing salpingitis, or the peritoneum, causing inflammatory deposits about the ovaries and the orifices of the tubes. Neglect may be productive of salpingitis, cellulitis, oöphoritis, peritonitis, the formation of abscesses, the destruction of organs, and not infrequently loss of life.

Treatment.—Prophylaxis is the most important consideration, and will demand rigid asepsis during labor and in gynecologic examinations. The occurrence of hemorrhage, offensive lochia, or elevation of temperature should be considered as an indication for careful investigation. Lacerations of the cervix should receive early attention. The early employment of the curette should be regarded as indispensable. The latter should be supplemented by intra-abdominal

methods where the inflammation has passed beyond the uterine cavity to the deeper pelvic structures. These cases are frequently subjected to intra-uterine treatment, but it should be employed only after ample drainage of the canal has been secured. To attempt the application of remedies through a small canal is but adding insult to injury, and is inviting the development of worse conditions than that for which the treatment is instituted. The inflamed uterine canal is similar to a sinus—unless it is freed from the irritating discharges, the disorder is aggravated. In the senile variety the indication of first importance is free drainage. This alone is sufficient to establish a cure, and may be secured by the insertion of a hard-rubber or glass drainage-tube, as suggested by Wylie. The recovery is expedited by occasional irrigation with an antiseptic solution.

Chronic metritis is an inflammation of the muscular structure of the uterus, and, to a more or less marked degree, associated with endometritis. When long continued, there is a great increase of the connective tissue, the uterus is hypertrophied, and in the later stages firm and hard. The condition is quite analogous to the changes the liver undergoes in cirrhosis. An effort is made by some English authorities to distinguish between it and subinvolution, but they are only different stages in the same process. In the early stage the organ will be flabby and soft, but with the increase of the connective tissue it becomes as firm as a mature fibroid growth. The organ is uniformly increased in size.

Etiology.—Chronic metritis is ascribed to two classes of causes—the predisposing and the exciting. The former is subdivided into—(*a*) those which interfere with the normal involution of the uterus, and (*b*) those produced by repeated and protracted congestion. To the first class belongs retention within the uterus of portions of the placenta, decidua, or blood-clots; lacerations of the cervix and pelvic floor; pelvic inflammations; non-lactation; too short convalescence following delivery and repeated abortions. To the second class belong displacements, malformations, congenital anteflexion, the presence of tumors in or near the uterus, improper clothing, exposure to cold, and masturbation. The exciting cause is the existence and action of microörganisms.

Symptoms.—The patient will frequently attribute the condition to a previous labor or to repeated abortions. There are no characteristic symptoms, but the same symptoms are present as are common to cancer, myomata, displacements, and other local disorders. The patient complains of weakness, want of interest in anything outside herself, and disinclination to exertion. Standing and walking are irksome, from the sensation of weight and pressure and the feeling that her viscera are about to be extruded. There are points of anesthesia over the surface of the thighs, and frequently partial loss of power of the lower extremities. I have seen the patient present the symptoms of locomotor ataxia, which entirely disappeared after the relief of the irritation. Painful contraction of the uterus, irritable

bladder, constipation, loss of pleasurable sensation during coition, pricking of the eyes, weak sight, photophobia, coronal headache, occipital pain, disturbance of the menstruation, as dysmenorrhea, amenorrhea, menorrhagia, and irregular bleeding are among the train of symptoms ascribed to this disorder. The patient becomes pale and weak, has frequent attacks of palpitation, and is often greatly depressed. Neurasthenia, hysteria, epilepsy, and acute mania are not infrequently developed and generally aggravated by this condition.

Signs and Diagnosis.—The uterus is uniformly enlarged, soft, and pliable in the early stages, hard, dense, and firm in the later. It may retain its normal position or undergo some form of displacement, be freely movable, or fixed by inflammatory exudate. The conditions with which chronic metritis are most likely to be confused are pregnancy, carcinoma of the uterine body, small interstitial or submucous fibroids, and disease of the rectum. Pregnancy in its early stages will be characterized by arrest of menstruation and an increased discharge; the body of the uterus is comparatively so much greater than the cervix as to give an impression of a jug-shaped enlargement; the body is not resistant, and the cervix is soft. Cancer in the majority of cases involves the cervix; where the body is involved, the organ presents points of hardness as a result of the infiltrate, rather than uniform hardness. In some cases it may be necessary to dilate the uterus with tents to permit the digital exploration of the cavity and the employment of the curette, and the microscopic investigation of the scrapings in order to insure the diagnosis. Small interstitial and submucous fibroids in a large uterus are difficult to differentiate from the chronically inflamed organ. Where the abdominal walls are thin and the patient relaxes her muscles, the limited area of resistance favors the recognition of the growth. When the metritis is complicated by pelvic inflammation, the growth may very readily be overlooked. Disease of the rectum may cause symptoms which simulate chronic endometritis.

Treatment.—The only effective plan of treatment is the preventive. Neither medical nor surgical measures will restore an organ to its normal condition after marked tissue change has occurred. Sexual rest, judicious exercise in the open air, regular evacuation of the bowels, proper hygiene, hot douches, and medicated tampons will be of value. Injuries of the uterus and pelvic floor should be repaired. The uterus should be curetted, and under some conditions the cervix amputated. Where the condition has existed for a considerable time and is complicated by tubal or ovarian disease, the preferable procedure is to remove the uterus with its appendages. The removal of the organ relieves the imprisoned nerves, which are compressed by the increased connective-tissue growth.

Curettage.—In the preceding pages we have frequently advised the employment of the curette. It is an instrument capable of much good and of more harm. It may be considered to be indicated after

an abortion or labor, when the symptoms indicate the retention, within the cavity, of clots, portions of the placenta, and decidua, or where hemorrhage or profuse discharge occurs; in chronic inflammation of the endometrium of the cervix or body; in all cases in which operations are done on the cervix, or where the abdomen is opened to treat disease of the appendages, with the purpose to save one or both; as a preliminary to operations for the object of maintaining a displaced uterus in a correct position, and to secure material to confirm the diagnosis in suspected malignant disease. It should be considered as contraindicated in malignant disease, except to secure material for examination and as preliminary to radical operation; in submucous fibroid tumors, as the instrument is likely so to injure the growth as to imperil its vitality; in every inflammatory case where the infection has extended to the tubes, the pelvic peritoneum, and the cellular tissue, unless its employment is immediately followed by an abdominal incision for the correction of the intra-abdominal lesions; and never where there is the suspicion of pregnancy.

Technic.—The preparation will depend to some degree on the condition for which it is practised. The first aim should be to render the vagina as nearly aseptic as possible; hence it is washed with a mixture of tincture of green soap and water (1:16). This is removed by washing with sterile water, and, finally, the vagina is scrubbed with alcohol (50 per cent.) in water. Not only the vagina and vulva are thus scrubbed, but the buttocks and every part which is likely to be touched during the operation. The operative field is surrounded with an aseptic sheet, the cervix exposed, seized with two double tenacula, as the two are less liable to tear out, and the dilatation is done by graduated bougies, two sizes on each handle. These bougies, especially the smaller sizes, should be employed with care, as the wall of the uterus may be very easily punctured. In the larger sizes the wall may be ruptured in acute flexions, as the wall is thinned on the side opposite to the flexion. The dilatation is done by many surgeons with the parallel-bar dilators, but they offer no greater safety from perforation, and when such injury occurs and is not observed before the separation of the blades, it may be almost irreparable. The dilatation is followed by the use of the curette, which should be fenestrated and sharp, with a tubular handle which can be connected with a douche-bag, and the blood and scrapings washed away as the instrument passes over the surface. Particular care should be exercised in the use of the instrument to curette the entire uterine cavity. After its completion the uterus can be packed with medicated gauze, swabbed with some solution, or permitted to drain without interference. In an infected uterus I believe it better to employ iodoform gauze packing, as it keeps the surfaces apart and favors the closure of the uterine sinuses. In uninfected cases it is my custom to swab the cavity with a saturated solution of iodoform in ether; the ether rapidly evaporates at the body temperature, and leaves a coating of iodoform over the surface. Watson suggested

throwing into the cavity an ounce of a 3 per cent. solution of formalin in glycerin.

Dangers.—The use of the curette is by no means free from danger. Its employment is not infrequently followed by extension of infection to the deeper structures, but this can be avoided by the exercise of proper asepsis and care in the selection of suitable cases. Perforation of the uterine wall with the curette or the dilating instruments is of not infrequent occurrence. This accident is very prone to occur in the recently inflamed uterus or in the woman who has had a recent abortion. Numerous instances are recorded where the first intimation the operator had of perforation was the appearance of a loop of intestine at the external os. The intestine has been so injured in some cases as to require resection. A patient came under my observation in whom the anterior wall of the uterus had been so spread apart by parallel-bar dilators that I had to remove the fundus uteri, and the woman subsequently died from sepsis. An ordinary perforation when the case has been managed aseptically is not a serious matter. The only treatment advisable would be to plug the uterus with iodoform gauze, when the convalescence will be as uneventful as if the injury had not occurred.

Hypertrophy of the Cervix.—The intravaginal and the supravaginal portions of the cervix are subject to enlargement. The latter is associated with prolapsus of the vagina, while the former occurs without any change in the position of the uterus or the vagina. It is a hyperplasia of the intravaginal portion of the cervix, which frequently becomes so elongated as to protrude from the vagina and lead the careless observer to believe that it is a uterine prolapse. The condition is determined by digital examination, which discloses that the vagina is of the normal length and is not affected by the elongation of the cervix. This condition is described by Auvard as pseudoprolapsus. The supravaginal elongation, also known as hypertrophic elongation of the cervix, is a not uncommon lesion, and is the result of loss of support from the pelvic floor, which permits the anterior and posterior walls of the vagina, with their related structures, to drag on the cervix until the entire uterus, or where it is fixed, the elastic cervix is drawn upon, causing elongation of its supravaginal portion. The anterior portion of the vagina is attached to the cervix at a lower level than the posterior, so that most frequently the elongation occurs between the attachments of the two portions. As a consequence, it will be seen that the entire anterior portion of the vagina is everted, while the posterior is of the normal length, and is not at all displaced. Here, again, the appearance is that of prolapsus, and from the contour of the tumor one is prepared to find the entire uterus in the mass, but grasping it between the thumb and fingers, it is found that there is a round, cord-like structure passing upward through the mass, which is recognized as the elongated cervix. The mass may consist of an increase of connective tissue only, or be associated with extensive cystic degeneration of the glands.

Treatment.—Amputation of the cervix is the only procedure of value in the treatment of either form of hypertrophy. In the intravaginal variety the amputation is done by splitting the cervix into an anterior and a posterior lip, and removing each lip with a double flap. The mucosa of the cervix and that of the portio vaginalis are carefully united front and back, to insure the new os, and the two lips are united laterally (Fig. 145). In the supervaginal form the vagina is separated from the cervix, if necessary as high as the peritoneal reflection, the amputation done as just described, except that in suturing the parts the bladder should be carried higher on the front of the uterus, or its posterior surface tucked up, after which the cervical mucosa and the vagina are sutured in front, and the remaining portion closed as above described (Fig. 146). As this operation is usually done for prolapsus, it is generally associated with plastic operations on the vagina, which will be described when considering the treatment of displacements.

FIG. 145.—DOUBLE FLAP AMPUTATION OF THE CERVIX WITH SUTURE INTRODUCED. (Montgomery.)

FIG. 146.—WOUND CLOSED IN DOUBLE FLAP AMPUTATION OF CERVIX. (Montgomery.)

Laceration of the Cervix.—Tears of the neck of the womb are among the most frequent sequelæ of parturition. These injuries may be unilateral, bilateral, through the anterior or posterior lip, or stellate. These may be nothing more than a slight fissuring of the os, or extend into the lateral fornices of the vagina, or through the anterior lip until the bladder is opened. Probably the bilateral laceration is the most frequent, and next, the left lateral, due possibly to the greater frequency of the position of the occiput to the left anterior.

Etiology.—The occurrence of laceration of the cervix is rendered probable by the previous existence of protracted endocervicitis. The lesion may be the direct result of too precipitate or of prolonged labor. In the former, by the energetic contractions of the uterus, the head of the child is driven through the os before the cervix has had an opportunity to become relaxed and dilated. In the prolonged labor the overhanging portion of the cervix is bruised between the pelvic bones and the head of the child until it becomes edematous and thickened, and finally gives way. An inordinately sized child,

malposition of the fetal presentation, misdirected expulsive force expended against an overhanging lip instead of the center of the os, premature rupture of the amniotic sac, hasty and unwise efforts to expedite the delivery, either manual or instrumental, are some of the important factors in the production of laceration of the cervix.

FIG. 147.—BILATERAL LACERATION OF THE CERVIX. (Munde).

FIG. 148.—UNILATERAL LACERATION OF THE CERVIX.

Stellate lacerations are the result of repeated labors (Fig. 149). Nature has made an effort to repair the earlier injuries, and in the subsequent labor the site of the original laceration, being the strongest portion, the tear occurs in a new situation. After a number of labors the cervix may thus assume a rather remarkable appearance.

FIG. 149.—EXTENSIVE STELLATE LACERATION OF THE CERVIX. (Munde.)

Symptoms and Signs.—No special symptoms can be presented as characteristic of cervical tear. They are produced by the complications of the lesion. Endometritis and subinvolution are sequelæ, and from them occur disturbances of menstruation, increased discharge, the sensation of weight and bearing down, discomfort in standing and during locomotion, and pain in the sacrum and iliac regions. A granulating cervix may be the cause of bleeding following coition or digital examination. To the formation of cicatricial tissue in the angles of the tear are attributed various nervous manifestations supposed to arise from the nerves pinched by the scar tissue. Digital examination discloses an enlarged os torn on one or both sides, or extensively fissured in different directions. The laceration may be slight—a mere enlargement of the os transversely or be very extensive, so that the tissue of the lateral fornix of the vagina is opened on one or both sides, or fissuring may be recognized in the anterior or

posterior lips, and in all these situations at the same time. Without apparent extensive lateral laceration the finger may pass nearly to the internal os. The cervical lips may be thin,—mere folds of tissue formed by the tears without hypertrophy,—or they may be enlarged and the lips be widely separated. The heavy, subinvoluted organ drags downward, and the attachments of the vagina being unantagonized, draw the lips forward and backward; the tender cervical mucosa being subjected to insult and injury with each breath the patient draws, with every exertion, and during the act of coition becomes inflamed and thickened; its glands become obstructed and form retention cysts. The efforts of nature to obviate the condition result in plastic exudate, granulation tissue, and the formation of a cicatricial mass by which the lips are widely everted. In such a state the finger reveals the lower end of the cervix as its largest portion, while the neck above is small. Occasionally involution will take place in the posterior lip, while the anterior, in the axis of the vagina, becomes greatly hypertrophied. It is not unusual to find a marked disproportion in size between the two lips. The increased weight of the uterus and the diminished support of the cervix permit the organ to drop to a lower level and form the first stage in prolapsus. While the laceration is extensive but unilateral, the separation of the tear causes the fundus to incline toward the side of the lesion, and a lateral version results. The everted mucosa and its thickening by the inflammatory deposits sometimes so obliterate the fissure as to cause it to be overlooked.

Diagnosis.—The finger affords the best means of recognizing the lesion, but the fact that a fissuring of the cervix is determined is not to be accepted as proof positive of previous pregnancy, for a congenital separation of the lips can exist which will permit as marked eversion as from the laceration. The presence or absence of changes in other portions of the genital canal will be confirmatory of the diagnosis. Its extent and character are readily recognized by the digital examination. The latter discloses the amount of repair which has been accomplished, the extent of the cicatricial changes, the condition of the mucosa, its thickening, eversion, the presence of the distended glands of Naboth, the spread-out cervix, and the contracted portion above. The indurated surface covered with granulations and cysts of Naboth, the profuse discharge with offensive odor where cleanliness is neglected, and the bleeding from slight manipulation lead not infrequently to the diagnosis of carcinoma. Experience has shown that the existence of laceration is a condition favoring the development of carcinoma, and where the diagnosis cannot be determined by examination and inspection, a section of the tissue should be excised for microscopic investigation. In excising the tissue it should be so done that the sections for examination may include both the healthy and the suspected structures. The extent and character of the laceration are best inspected by the employment of a Sims speculum or a retractor. The ordinary bivalve

speculum, by its traction on the vaginal walls, either exaggerates the laceration or so obscures it that it escapes observation.

Treatment.—The immediate repair of a lacerated cervix is not generally practicable, because the cervix, directly after the labor, is so spread out and thinned that it is difficult to determine the extent of the lesion. Where the perineum is also lacerated, the better procedure is to wait five or six days after the delivery and then repair both the cervix and the pelvic floor. The delay has the double advantage that it permits the structures to resume to some degree their normal outlines, and if there has been any doubt as to the asepsis, an opportunity has been afforded for its manifestation before the parts have been closed. Operation then promotes normal involution of the uterus and diminishes the danger of endometritis. Small lacerations are likely to heal if the surfaces are kept aseptic. Lacerations of the cervix of the secondary variety come much less to operation than formerly, for two reasons: first, experience has taught that it is better not to repair the small tears because drainage is impaired and the danger of sequelæ increased; and, second, the better asepsis in the practice of obstetrics promotes the repair of injuries without operation.

Care must be exercised in the selection of cases for operation, as patients with tubal or peri-uterine disease are prone to a redevelopment of the inflammatory condition if the injured cervix is repaired without subjecting the abdominal disorder to proper treatment. Further, the cervix should not be repaired without the treatment of the other complications. The existence of various complications, as endometritis, relaxed and lacerated pelvic floor, and displacements of the uterus, has been referred to, and their presence requires the employment of measures for their relief as complementary to the repair of the cervical lesion. In many cases the operation on the cervix should be preceded by local treatment. The engorged structures should be depleted through repeated scarification, obstructed glands punctured, and their cavities painted with iodin to accomplish their obliteration; the uterus should be raised and supported by medicated tampons, preferably with a preparation of glycerin, which still further depletes the organ, and, by maintaining it at a higher level, promotes the involution. No laceration of the cervix exists for a length of time without producing endometritis, so the curetment of the uterus should be considered a necessary part of the operative procedure.

Trachelorrhaphy or **hysterotrachelorrhaphy** was the operative procedure devised by Emmet for the repair of lacerated cervix. The patient should be prepared in the manner indicated for the curetment of the uterus. The patient being in the lithotomy position, the cervix is exposed by the Edebohls speculum, is held by a double tenaculum in each lip, and with a scalpel the surfaces to be denuded are outlined. Care is exercised to leave a strip one centimeter wide in the center of each lip for the future cervical canal (Fig. 150). This

undenuded portion should widen slightly at the outer surface. As far as possible the denudation should extend equally on each lip and into the angles, so that all new-formed tissue is removed. This bilateral denudation, of course, applies only to the double tear, and then only when the laceration is an extensive one; in the slighter tears it is better to make the denudation on the side of the greater depth than to denude both sides. In the introduction of the sutures I prefer to insert the sutures which will form the margins of the new os first, and then remove the tenacula, using these sutures to control the cervix. Placing these sutures at once makes sure of keeping the two lips of proper length (Fig. 151). The remaining sutures are introduced about three millimeters apart, and the same distance from the edge of the wound on the vaginal surface, brought out at the margin of the cervical mucosa, on the one lip, carried into the opposite lip at a similar point, and brought out on its vaginal surface. All the sutures are introduced before any are tied, the lips are separated, blood-clots

FIG. 150.—DENUDATION FOR REPAIR OF BILATERAL LACERATION OF THE CERVIX. (Montgomery.)

FIG. 151.—BILATERAL LACERATION OF THE CERVIX AND SUTURES INTRODUCED FOR UNION OF DENUDED SURFACES. (Montgomery.)

removed, and the surfaces united. The first sutures introduced are the last tied. The ends of the sutures are cut, the field of operation cleansed and a pad of iodoform gauze placed over the cervix. The operation requires for its ready performance three assistants beside the anesthetist, two of whom may be nurses. The following sterile instruments should be placed in a tray on a table at the right of the operator: a scalpel, curved scissors, long rat-toothed tissue forceps, two double tenacula, a retraction speculum (Edebohls'), six hemostatic forceps, a needle-holder, and four strong curved needles, each threaded with silk, to serve as a suture carrier. A smaller tray will contain the suture material. An assistant on either side can hold a leg covered with a sterile sheet, or the legs can be secured with a leg-holder. The assistant to the operator's right attends to the necessary sponging and holds the ligatures attached to the end of the cervix when the sutures are introduced on the right and during the tying of the same. The left assistant holds the tenaculum in the anterior lip during the denudation and manages the irrigation tube. The

tenaculum hanging from the posterior lip keeps the cervix open; after the introduction of the end sutures the assistant holds these, while the left sutures are introduced and tied. The third assistant hands sponges, sutures, and does such other work as may be demanded. The sponges may consist of pads of sterile gauze or sterile absorbent cotton, the latter wet with 1: 2000 sublimate solution. When irrigation is done, the hot normal salt solution is preferable. The sutures may be sterile silk, silkworm-gut, silver wire, or chromic catgut. I prefer the latter because, in the majority of cases, several operations are combined in which the pelvic floor is also restored, and the removal of non-absorbable sutures is attended with so much difficulty and discomfort to the patient that it seems desirable to avoid the necessity for removal when possible. The performance of the operation above described is not desirable in every case of laceration; indeed, is of limited application. It may be considered as indicated in recent laceration, and in those in which there is but little thickening and slight inclination to eversion of the cervical mucosa. Where such changes are marked, the operation would lead to an obstructed canal and defective drainage. In all cases, then, of marked thickening and eversion of the mucosa, the operation of choice should be that of amputation.

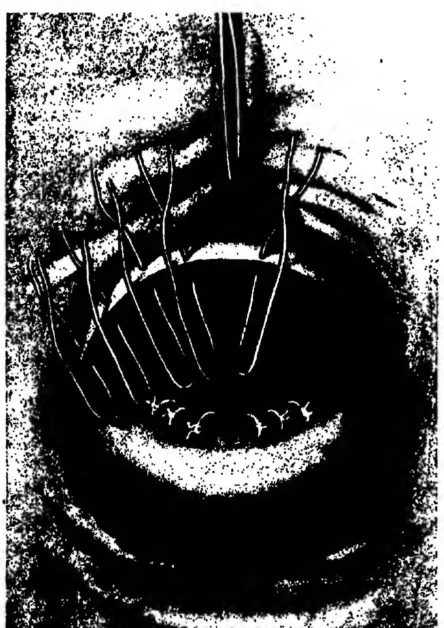


Fig. 152.—Schröder's Single-flap Operation.

Amputation of the Cervix.—The cervix may be amputated by the double-flap or the single-flap method. The former has been described under hypertrophy of the cervix. The latter method, also known as Schröder's operation, is the one most frequently chosen in lacerated cervix. The same instruments and a similar number of assistants are required as in the operation for laceration. The lips of the cervix are widely separated, and an incision is carried half through the cervical wall, encircling the opening of the canal at the summit of the laceration (Fig. 152). Below this incision the inner surface of each lip is removed to the junction of the vaginal and cervical mucous membranes, at the site of the original os. The mucosa of the cervix is united to that of the vagina, front and back, by three sutures each, and the raw surface on each side sutured as in an ordinary operation

for amputation. This procedure removes the diseased mucosa, with as slight shortening of the cervix as is possible.

Wounds of the Uterus.—The uterus is so protected in its situation within the bony pelvis that it is rarely injured unless through operative interference. The most frequent injuries are those which occur during the operation of curettage, and especially the removal of portions of the placenta after an abortion. The walls of the uterus, under such circumstances, and when it is inflamed, are very soft, and puncture may occur with the very slightest pressure—so slight that the occurrence of the injury escapes the notice of the operator. Perforation, also, occurs during abortion when practised by the victim or at the hands of another. These wounds are the most dangerous for the reason that they are generally produced without any consideration of the principles of asepsis, and the case comes under the observation of the surgeon when the development of the infection makes the condition desperate. The ease with which perforation occurs in emptying the uterus after abortion makes wise the advice to employ the finger as a guide in all manipulation of instruments within the uterus for the purpose of the removal of fragments of the placenta. Failure in observing this rule has caused the operator, in a number of instances, to be surprised by seeing a coil of intestine in the grasp of his placental forceps at the external os. Perforation of the uterus by the bougie in dilatation of the canal, where the conditions are aseptic, calls for no especial treatment. It has been my custom, when the perforation is recognized, to pack the uterus with iodoform gauze after the curettage, and not to use the flush curette nor to mop out the cavity with a medicated solution. The occurrence of the injury exerts no influence on the convalescence. That perforation occurs much more frequently than is suspected is evident from the great number of cicatrices seen in the fundus when the abdomen is opened later for other conditions.

Rupture of the uterus is an accident of parturition, although it may also occur, though less frequently, during pregnancy and in the puerperium. According to Edgar, it occurs about once in 1000 cases. During pregnancy it is produced by rapid stretching of the uterine walls or from cystic degeneration of the chorion. In the puerperium it occurs from sloughing of the uterine wall, from protracted pressure of the child's head during the labor, and from a septic dissecting metritis. In the Philadelphia Hospital I had a patient who lost her entire fundus from this cause.

In the greater number rupture occurs during parturition, and most frequently on the left side and the posterior wall. The left lateral tear is likely to push the peritoneum before it, so that the cavity remains unopened, and as a result a hematocele may form which is both extra-uterine and extraperitoneal. The opening varies from the size of the finger-tip to one which will permit escape of the fetus and the contents of the uterus. The lesion may be transverse, involving a good part of the circumference of the uterus, or longitudinal,

extending into the vagina, or upward to the fundus. The rupture may be incomplete or complete. In the former the injury involves the muscular layer; in the latter, it extends through the peritoneum. The rupture is called complicated when neighboring viscera, as the bladder and intestine, are opened.

Etiology.—The causes have been divided into the predisposing and exciting. Among the former may be considered a marked disproportion between the size of the child's head and that of the pelvis, stretching of one side of the uterus by a transverse position of the fetus, as in a shoulder presentation, narrowing or rigidity of the cervix from previous operative procedures, the scar of a previous Cesarean section, obstruction from deformity of the pelvis, weakening of a part of the wall, and a rigid ring from cancer of the cervix. It is seven times more frequent in multiparæ than in primiparæ. The exciting causes are the injudicious administration of ergot, unskilful manual and instrumental interference with labor.

Symptoms.—In a woman with some pelvic deformity or obstruction to delivery strong tetanic contractions, suddenly followed by sharp cutting pain, a sound of tearing tissue, a feeling on the part of the patient of something giving way, followed by profound collapse and all the symptoms of an internal hemorrhage, are characteristic. Collapse is not always present, but there are generally symptoms of peritonitis. The process may terminate in one of three ways: in contraction and closure of the rupture, in rapid death from internal hemorrhage and collapse, or in retarded death from the development of peritonitis or septicemia.

Diagnosis.—The fetal heart-sounds suddenly cease. Rupture of the uterus is generally associated with the death of the fetus. Vaginal palpation discloses that the presenting part has partially or completely receded, the cord, portions of the omentum, or coils of intestine may be felt at the external os, the introduction of the hand into the uterus discloses the rent in the uterine wall, which may be small or so large that the contents of the uterus have escaped into the peritoneal cavity. Palpation of the abdomen in such cases reveals two bodies, the one more or less contracted—the uterus—and the other, the fetus within the abdomen. The accident is always of the gravest import, and demands prompt consideration.

Treatment.—Edgar divides the treatment into the prophylactic and the curative. The former consists in careful watching of a case presenting conditions favorable to rupture, the administration of morphin or an anesthetic to modify the severity of the uterine contractions, and, where the conditions do not give promise of being readily overcome, for the interests of both mother and child, the Cesarean operation should be performed. The curative treatment has to deal with the case after the occurrence of the rupture, and comprises, first, the delivery of the fetus by some method, podalic version, forceps, or, when dead, craniotomy, which will relieve the tension and accomplish the delivery most easily. Second, careful

examination of the site and extent of the rupture. Third, when small and situated low down in the uterus, and clots and meconium have not escaped into the abdomen, though this is difficult to determine, the uterus may be irrigated with salt solution, a strip of iodoform gauze carried to the fundus, and ergot administered. The patient should be carefully watched for signs of peritonitis, which should be considered an indication for abdominal incision and drainage. Fourth, in large ruptures the abdominal cavity should be opened and the fetus and placenta, if they have escaped into the cavity, removed. When the fetus has been delivered and the presence of a large rupture is recognized, the patient may occasionally recover after packing the wound and the uterus with gauze, but the more radical procedure of entering the cavity with the knife is the wiser and more conservative plan. The method of procedure must be decided by the previous management of the case. If it has been thoroughly aseptic, the rough edges of the tear may be trimmed, and the opening closed with several layers of catgut. If there is a reasonable probability of infection, it is wiser to remove the uterus by the Porro operation.

Cesarean section consists in the delivery of the fetus through an abdominal and uterine incision.

Indications.—This procedure may be considered as indicated whenever there exists any condition on the part of the mother or child which will produce such an obstruction to delivery as will imperil either, the child being viable. They are classified as follows:

1. Pelvic deformity. 2. Uterine neoplasms, as fibroids, carcinoma, etc. 3. Vaginal deformities, such as marked contraction from scars and tumors. 4. A very large child. 5. Eclampsia with a firm, undilatable cervix, and especially when complicated with deformed pelvis or placenta prævia. 6. Placenta prævia.

It is a well-recognized obstetric axiom that a conjugata vera of 10 to 11 cm. is necessary for the safe delivery of a normal fetus, and any reduction from this requires resort to some special expedient. The alternative expedients are the high application of the forceps, podalic version, symphysiotomy or its modifications, pubiotomy or hebosteotomy, craniotomy, and the various modifications of the Cesarean section. Both the forceps and version add to the morbidity and the mortality for the mother, and greatly increase the danger for the offspring in contracted pelves. Symphysiotomy and its modifications, with their advantages and disadvantages, will be discussed later. Craniotomy should never be considered when the child has a chance for life. When the conjugata vera is but 6.5 cm. or less, Cesarean section affords the only hopeful outlook for the mother. General contraction of the pelvis at the brim or outlet is equally disastrous, and demands the employment of special means to accomplish delivery. In late years the employment of Cesarean section is regarded as proper treatment for placenta prævia, especially of central implantation. As for eclampsia, it may be safely questioned whether this procedure is as worthy of consideration as other measures which

will be discussed later. Cesarean section should always be considered the operation of choice when the judgment of the capable obstetrician is satisfied that it affords both mother and child the best prospects for life.

Time for Operation.—It was formerly considered time for the Cesarean section when the other methods had failed to accomplish the delivery, but the mortality of the operation was so great that it became manifest that the educated accoucheur should know when the patient was able to deliver herself, and be prepared in advance to apply the measures for the successful management of the individual case. Reynolds, after a careful analysis of 289 cases by 20 different operators, divides the cases for Cesarean operation into three classes, which he calls primary, secondary, and late. (1) Primary include those in which the patient is subjected to operation in advance of labor or at its very beginning. (2) Secondary sections, those performed after a certain amount of labor has demonstrated its probably unsatisfactory character, but before exhaustion has set in, and before it has been definitely established that the natural powers will fail to effect the passage of the brim. (3) Late sections: those performed after definite arrest of the head at the brim. The value of early operation was well demonstrated by the results of the table cited; 82 were operated on prior to the beginning of labor, with one death, or a mortality between 1 and 2 per cent. One hundred and fifty-eight were operated on early in labor, with 6 deaths—a mortality of 3.8 per cent.; and 49 after the arrest of the head or an unduly long first stage, with 6 deaths, or 12 per cent. mortality. Reynolds reported 30 cases operated on by himself, without a death. It is not in the absence of or in low mortality only that the early operation is of advantage, but in the lessened anxiety about the patient occasioned by the smooth and uninterrupted convalescence. The operator is able to choose the time for the operation and make the better preparation.

As the result of experience in a New York Lying-In Hospital McPherson reports 30 sections with 4 still births, a fetal mortality of 4.08 per cent. Of the entire 186 sections performed during the eighteen years of the existence of the hospital, there were 13 still births—a mortality of 6.9 per cent.; in the last 108 cases there were but two stillborn.

Preparation.—The bowels and bladder are emptied, the latter, if necessary, with a catheter. The vagina, vulva, and the abdomen are carefully scrubbed, with the patient on a suitable operating table and covered with sterilized towels.

Instruments.—A sharp scalpel; scissors, straight, curved, and bent on the side, the inferior blade probe-pointed; a dozen hemostatic forceps; tissue forceps; two double tenacula; needle-holder, and a number of suitably curved needles; catgut, chromicized, No. 1 and 2, should be at hand in a tray and sterile silk and silkworm-gut.

Operation.—The assistant presses the uterus against the abdominal wall by a hand on either side of the abdomen, while the operator makes

an incision 12 cm. to 15 cm. long, terminating about 5 cm. above the umbilicus. The uterine incision is made of same length; gauze pads or preferably a long gauze pad is packed between the abdomen and the uterus, to absorb the escaping amniotic fluid. The site of the

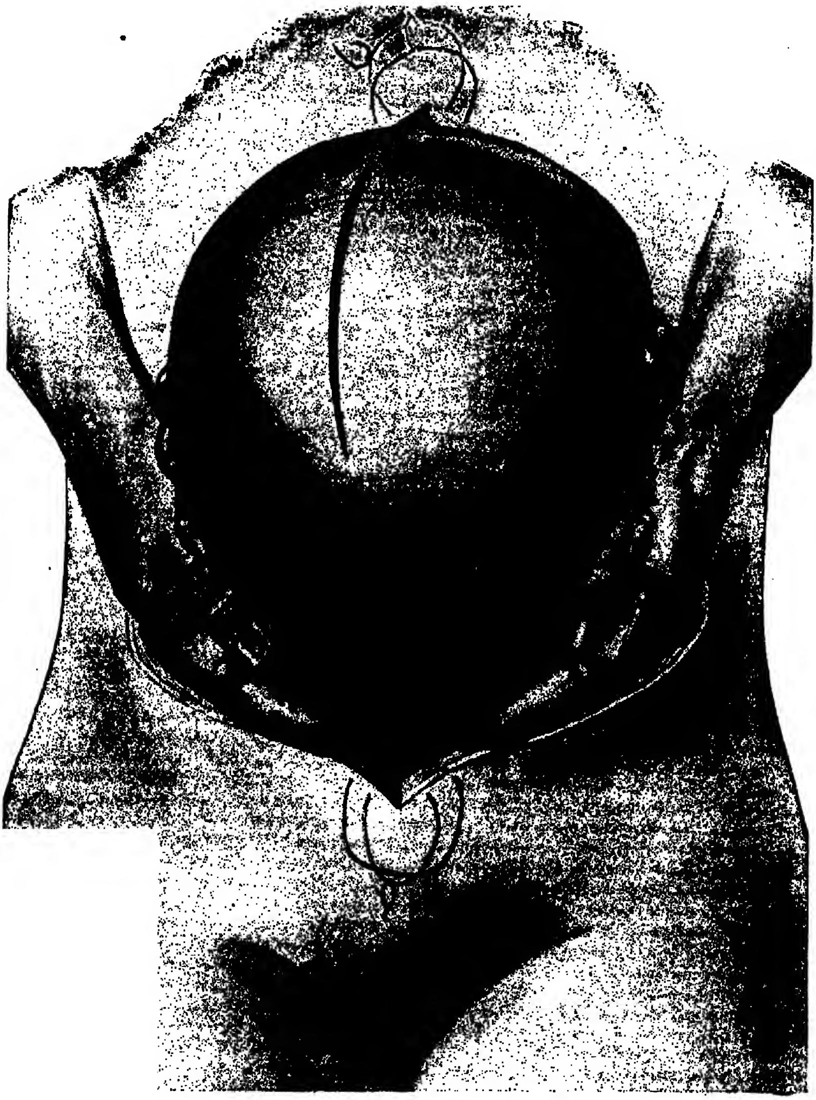


FIG. 153.—CESAREAN SECTION. (Edgar.)

uterine incision should be made with reference to the attachment of the placenta, in order to avoid going through it. Extensive observation has shown that the attachment of the placenta has the following relation to the position of the fetus: (1) L. O. A. the placenta is attached to the posterior and the right; (2) R. O. A. to the posterior

and the left; (3) R. O. P. to the anterior and to the left, and (4) L. O. P. to the anterior and to the right. The hand is pressed through the membranes, and the fetus seized by the feet or breech and rapidly extracted, while an assistant makes pressure on the uterine arteries in the cervix. The umbilical cord is cut between hemostatic forceps, and the child given to an assistant, who proceeds to resuscitate it and establish respiration (Fig. 153). During this time the first assistant keeps the uterus crowded into the wound, where it is surrounded with gauze pads. The placenta and the membranes are removed with the hand, and the uterine cavity wiped with gauze. If the uterus is well contracted, the sutures are at once introduced, otherwise it should be

FIG. 154.—CESAREAN SECTION. CLOSING UTERUS.

well packed with gauze and pressure made against it from the outside. Interrupted No. 2 twenty-day chromic catgut sutures are introduced about 2 cm. apart, through two-thirds of the muscular layer, but not into the mucous membrane; a second row of sutures between these includes a portion of the peritoneum and the outer third of the muscular layer. After these two layers are tied and the ends of the ligatures cut short, a No. 1 continuous catgut suture draws the peritoneum over the wound.

Various modifications of the operative technic have been suggested, as going through the right rectus muscle instead of the middle line. Sinclair, after closing the uterine wound, obliterates the

vesico-uterine pouch and brings this peritoneum over the wound to secure adhesions. Fritsch advocates a transverse incision through the fundus for the delivery of the fetus, which permits the closing sutures to be inserted vertical to the vessels. Frank, of Cologne, attempted the operation extraperitoneally by a transverse incision through both the abdominal parietes and the uterus just above the pubes. The vesico-uterine peritoneum was pushed back, and the peritoneal cavity left unopened. Veit followed the same principle, except that he made a vertical incision through the abdominal wall, and Selheim employed the Pfannenstiel incision. It was not always found possible to push up the vesico-uterine fold, so all these operators have made the transperitoneal incision, dissected up the peritoneum from the front of the cervix, and united the edges of the cervical and parietal peritoneum before opening the uterus. The purpose of these procedures has been to avoid infection of the peritoneum, as it is impossible to say whether the individual is infected, as not infrequently these women examine themselves or have the examination made by a companion. It is always wise to regard the patient as infected who has been in labor for some time without aseptic care, or where repeated examinations have been made by persons whose methods are doubtful. In the effort to prevent the infection of the peritoneum a very complicated wound is made, which opens up a large amount of connective tissue which is less resisting to infection than would be the peritoneum.

Abdominal-cervical Cesarean section is the title given by Pfannenstiel to the procedure, which he performs as follows: A transverse incision, about 15 cm. long, is made at the level of the anterior superior iliac spines through the skin, superficial fascia, and aponeurosis, and the latter separated to the symphysis and umbilicus respectively; the recti muscles are separated, and the peritoneum opened for 10 cm. longitudinally. Then the peritoneum, carefully guarded by sponges, is opened between the bladder reflection and the contraction ring, and the vagina opened. If the operation is delayed until the cervix is dilated, the bladder rests directly against the vagina, and it is unnecessary to separate it. When the vesico-uterine plica is still high, it should be cut across, and with the bladder stripped down, as in hysterectomy. The child is extracted by lateral pressure or by the feet. After a short pause, occupied in changing the pads, the placenta is delivered either spontaneously or by pressure through the abdominal wall. The cervical wound is sutured in two layers.

The advantages claimed for the procedure are: (1) (*a*) The probability of morbidity and mortality is diminished because the uterus remains in situ and the peritoneal cavity is protected from contamination. (*b*) All danger of hernia is eliminated. (*c*) The patient is able to leave her bed as early as the third day. (2) The possibility of hemorrhage is reduced to the minimal because—(*a*) no large vessels are incised, and (*b*) the detachment of the placenta is left to nature.

Vaginal Cesarean section is an operation devised by Dührssen especially for rapid delivery in eclampsia, and according to its author

has the following indications: 1. Danger to the life of the mother, caused by abnormalities of the cervix uteri and of the lower uterine segment (carcinoma, myoma, rigidity, stenosis, partial dilatation of the lower uterine section), abnormalities which make impossible the dilatation of the cervix by the uterine contraction or render it very difficult. 2. Dangerous conditions of the mother, imperiling life, which are removed or moderated by evacuation of the uterus (diseases of the heart, of the lungs, and of the kidneys, premature detachment of the placenta). 3. Conditions which presumably may occasion the mother's death. 4. Danger to the life of the child without the presence of danger to the mother at the same time.

Operation.—After evacuation of the bowels and bladder, thorough cleansing of the vulva, vagina, and environment, and an enema of ergot, a perineovaginal incision is made on the right side in primiparæ. If this incision is carried through the levator ani muscle, a large fist can be carried into the vagina, and the parts are held open by large retractors, which serve to control hemorrhage, thus dispensing with the necessity for the immediate employment of ligatures. The cervix is seized and drawn down by a double tenaculum on each side, and threads are substituted. The posterior lip is divided to the vaginal attachment, and then an incision, 4 cm. long, made in the posterior fornix, and the peritoneum bluntly dissected from the cervical and corporeal wall. Similarly, the anterior lip and vaginal fornix are divided and the peritoneum pushed back. The anterior and posterior uterine walls are further split with scissors, the uterine cavity quickly entered with the hand grasping a foot, and the fetus rapidly delivered. If the uterus contracts, the spontaneous delivery of the placenta may be awaited, otherwise it should be detached manually and a uterine tampon of gauze inserted. The uterine incisions are closed with interrupted catgut sutures tied on the external surface of the organ, after which the two vaginal wounds are closed by continuous catgut sutures, leaving an opening in each near the uterus for a gauze drain. The procedure is completed by closure of the perineovaginal incision. He closes the vaginal portion with catgut and the perineum with silkworm-gut sutures. This operation is of especial value in eclampsia with rigid cervix, and in cancer of the uterus where the delivery can be immediately followed by the removal of the diseased organ.

Porro-Cesarean section is an alternative operation to the Cesarean section when the child is alive, and is a supravaginal hysterectomy. The ordinary Cesarean section may be repeated several times on the same individual, but the Porro operation is a mutilating procedure, so that after its performance further procreation is prevented. It is to be preferred to the Cesarean when the patient has been long in labor, and the uterus has become so bruised as to render its retention dangerous to the woman, or in cases in which infection has been introduced. It is also considered as indicated in the destitute and illegitimately pregnant, especially when suffering from tuberculosis or cardiac disease and delivery has to be accomplished by laparotomy.

The necessity for operation in such an individual should entail measures to prevent its recurrence.

Operation.—The abdominal incision and the delivery of the fetus are similar to those in Cesarean section. After the removal of the placenta, the uterine cavity is packed with gauze, the uterus brought out of the wound, and the intestines packed back with gauze, the patient being in the Trendelenburg position. The broad ligaments on each side are clamped with two forceps and cut between them, the round ligament likewise clamped and cut; the peritoneum in front of the uterus is cut. and with the bladder pushed down the broad ligament is spread out, exposing the uterine arteries, which are clamped, and the cervix cut across and the uterus removed. The clamped vessels are now ligated, and the peritoneum closed over the stump, which is dropped back and the abdominal wound closed without drainage. In the original Porro operation the stump was clamped and brought out at the lower angle of the wound and treated extraperitoneally. The prolonged convalescence, the difficulty in maintaining an aseptic wound, the weakened abdominal wall, increasing the danger of hernia, and the greater discomfort of the patient have caused this method to be discarded. As has been seen, the Porro procedure is advised for infected cases, but it has the objection that the portion most exposed to the infection—the cervix—is retained. Hysterectomy would seem the wiser procedure, and requires only that the entire cervix shall be removed. When the uterine arteries are cut, the uterus should be drawn to one side, and the vagina opened close to the cervix, and the latter encircled. Care must be exercised not to injure the ureters, which, owing to the size of the cervix, are more likely to be injured than in ordinary hysterectomy. After ligating the vessels, iodoform gauze may be packed into the pelvis, the end projecting into the vagina, the peritoneal surfaces are closed over the packing, and all ligated stumps turned into the vagina.

After-treatment.—The subsequent care of all these procedures is very similar: rest in the recumbent posture, careful observation, the early evacuation of the bowels, and gradual recourse to feeding when it is evident that nothing abnormal promises to mar the course of the convalescence. The vulva should be kept clean and have a continual aseptic dressing. If the patient finds herself unable to evacuate the bladder the employment of the catheter cannot be avoided, but the surfaces should be sponged with sublimate solution after every evacuation. The gauze packing should be removed from the vagina on the fourth or fifth day. After the fourth day, it is well to elevate the body of the patient to promote drainage, and in all cases encourage the patient to lie on either side, at intervals during the entire convalescence, instead of being confined to the back.

Symphysiotomy is a procedure for securing increased room in the pelvis by the division of the ligaments forming the two halves of the pelvis. It is an adjunct to other methods of delivery, as, *e. g.*, the application of forceps or version. It is indicated with a true con-

jugate of between 8.8 cm. and 6.7 cm., or supplemented by craniotomy where the conjugate is as low as 5.4 cm. It is indicated in impaction of the pelvis with a living fetus, in brow presentation, in funnel pelvis, and in the obstruction from kyphotic pelvis where the conjugate is 7.5 cm. or less. It is of doubtful expediency in mentoposterior positions. The entire pelvis must be considered before deciding on this operation. As it increases the size of the pelvis at the outlet as well as at the brim, it can be considered as indicated in the funnel-shaped pelvis, in the justominor, and in the normal pelvis, where the head of the child is of excessive size.

Operation.—There are three principal methods of performing the operation: 1. The French or open method. The mons veneris is shaved, and after proper cleansing of the surface, an incision, 8 cm. to 10 cm., is made in the median line, over the symphysis, to a point terminating just above the clitoris. The insertion of the recti muscles is partly divided, to permit the introduction of the finger into the prevesical space. The symphysis is divided by a few strokes of the knife from above downward and from before backward. If the separation of the bones is insufficient, it can be enlarged by flexing the legs and drawing the knees gently outward. The ligamentous mass beneath is divided last of all. A temporary dressing is applied to the wound, and the labor is allowed to progress. Some operators depend on subperiosteal sutures to maintain the bones in apposition during convalescence. 2. The Italian or suprapubic method. A transverse incision, 3 cm. long, is made 1 cm. above the symphysis through which a Galbiati knife is passed behind the symphysis as far as its lower border, and with a slight sawing motion cuts through the articulation. Novi uses for this purpose an ordinary bistoury, while Spinelli has devised a special symphysiotome. Morisani awaits the spontaneous expulsion of the fetus, and if this fails to occur, applies the forceps. 3. The subcutaneous or American method. The cervix is fully dilated, the urethra and the bladder are held to one side with a sound, while an incision is made a little above the subpubic arch, and beneath the elevated clitoris, through which a small tenotomy knife is passed, in front of the joint, and followed by a probe-pointed bistoury carried to the top of the joint, where it meets the point of the index-finger of the left hand, introduced into the vagina to guard the incision. The knife is carried down through the articulation until the latter is felt by the guarding finger to give way. An assistant presses gauze against the opening. If possible, the fetus is delivered by forceps, and when pressure comes against the pubic bones, the bladder is held to one side. After the completion of the labor, a small piece of gauze is pressed into the wound, and another larger strip is carried into the cervix. The vulva is kept dressed with aseptic gauze. The pelvis is rendered immobile by encircling it with wide strips of adhesive plaster. The operative procedure abounds in accidents, and the post-operative complications are not less formidable. Rubinrot's analysis of 136 cases showed 30 per cent. of septic accidents and ten

cases died of sepsis. Suppuration of the wound occurred in 10 per cent., and edema of the vulva in an equal number. Hematoma, abscess, stitch abscess, fistulas, permanent separation of the bones, lymphangitis, cystitis, incontinence of urine, paresis of the bladder, urinary fistula, bed-sores, infective myelitis, neuralgias, arthritis, and disorders of the sacro-iliac synchondrosis are some of the disasters charged against the operation. But these are not all. Later, there may be disturbance of the gait from permanent separation of the symphysis, sacro-iliac disease, discharge of bony sequestra, urinary incontinence, and fistulas, vesical paresis, cystitis, and sepsis. The mortality in the 136 cases was 11 per cent.—15 deaths, 13 from sepsis and 2 as a direct result of the operation. The infantile mortality was 19 deaths, or 14 per cent.

Pubiotomy, Hebotomy, or Hebosteotomy.—This procedure was devised by Gigli in 1893, to avoid the dangers incident to the operation of symphysiotomy, and was first performed by Bonard, of Lugano, in 1897. Gigli insisted on two important points: first, that the incision must be outside the articulation of the symphysis; second, it must be external to the pubovesical ligament, and lie entirely in bone instead of fibrocartilage. The thumb and index-finger of the left hand are placed above and below the symphysis pubis and the incision made to the right of them through all the tissues to the bone. With two fingers in the vagina to guide its course, a blunt needle is carried behind the bone. The thread carried by the needle serves to draw through a wire saw by which the bone is cut through and the operation thus finished. Döderlein modified the operation by substituting his subcutaneous method. A small incision is usually made over the left pubic tubercle, through which a blunt curved needle of special design is carried behind the bone to a counter-opening on the labium majus, followed by the Gigli saw, by which the bone is severed. Walcher and Bumm puncture the skin with the needle, and pass it with the guidance of the finger in the vagina.

The situation of the incision lessens the injury to the soft parts in the delivery, and thus makes the operation an advance over the operation of symphysiotomy. Of 294 cases of pubiotomy collected by Döderlein, 77 were treated by the open method, with a maternal mortality of 10 per cent.; the remainder were by the subcutaneous method, with a mortality of 4 per cent. Sarwey reported 120 cases of hebotomy, with a mortality of but 2.5 per cent., while in 216 cases of symphysiotomy the mortality was 12.8 per cent.

It would seem that a careful, though hasty, consideration of the operation of Cesarean section, with the alternative procedures, cannot but impress the conscientious practitioner with the value of the former procedure. It is applicable to every form of obstruction, while the substitute procedures have their limitations. Even in hebotomy, which is a great advance over the incision through the symphysis, in a small and rigid vagina, tearing is very likely to communicate with the section through the bone, greatly increasing

the danger of infection and prolonged convalescence As we have seen, hebotomy in the hands of careful men may have a maternal mortality as low as 2.5 per cent., and a fetal mortality of only 7 per cent., but Cesarean section in the same hands will show, when done prior to the beginning of labor, a maternal mortality of 1.2 per cent., and a fetal mortality of but 1 per cent.

Uterine Displacements.—The uterus, like the other viscera of the body, has a certain range of mobility, but has, in addition to the peritoneal and vascular support, elastic or muscular ligaments. The relation of the axis of the pelvis to that of the abdominal cavity, the position of the uterus in relation to the axis of the vagina, the direction of the latter, and the arrangement of the musculature of the pelvic floor are all factors in the maintenance of the uterus in its proper relation. As the uterus changes its position with every inspiration and expiration, with the varying movements of the body, with the empty or distended condition of the neighboring viscera, it is necessarily difficult to define what is the normal. The uterus is swung between the rectum and the bladder, occupying the axis of the pelvis, at right angles to the axis of the vagina, its fundus reaching to or a little above a line drawn from the promontory of the sacrum to the symphysis pubis, and the body slightly flexed forward on its cervix. Any continued deviation from this position must be considered a malposition.

Classification.—The uterus can be displaced upward, downward, forward, backward, and laterally. The classification, then, includes ascent, descent, dislocations, versions, flexions, and inversion.

Ascent.—Quite naturally the uterus cannot be displaced upward unless as the result of adherent growths, which become so large that they can no longer find accommodation within the pelvis, and, as they ascend, draw the adherent uterus with them. It may be pushed up by a collection of material in the pelvis. The condition requires no consideration or treatment beyond that demanded by the complication.

Descent or prolapsus uteri is probably the most frequent form of uterine displacement, and occurs in both the nulliparous and the multiparous woman, but with much greater frequency in the latter. According to its extent it presents three degrees: First, when the organ is situated at a lower level in the pelvis, frequently in the position of retroversion; second, when the os or a portion of the cervix protrudes from the vagina, and the third, when the uterus, with or without the vagina, is situated outside the vulva. The displacement may be divided into the incomplete and the complete; the projection of the third degree is a complete prolapsus, and is also known as procidentia. The condition is also divided into three varieties, according to its relations, as the uterovaginal prolapse, when accompanied by nothing more than the portion of the vagina normally enveloping it; vagino-uterine prolapse, when preceded by the vagina in the form of partial or complete inversion of that canal; and third,

pseudoprolapsus, when the cervix or os projects at the vulva, and examination reveals that the projecting portion is confined largely to the intravaginal portion of the cervix, which has undergone hypertrophy. In the second variety the prolapse of the vagina is, for the most part, confined to the anterior wall, and the examination of a mass which, from inspection, would be regarded as a complete prolapse, will be found to be a hypertrophic elongation of the supravaginal portion of the cervix.

Etiology.—Prolapsus is most frequently a sequel of parturition. The conditions productive of prolapsus may be divided into those causing decreased support, as laceration of the pelvic floor, overstretching of the musculature from repeated parturition, divulsion of the levator ani muscles, permitting a hernia of the subjacent tissues, a general loss of muscular tone, and a diminished inclination of the pelvis, which permits the intra-abdominal pressure to be more directly applied to the uterus. Second, increased weight of the uterus, as in subinvolution of the organ, the presence of growths within its walls, and changes resulting in chronic inflammation. Third, increased intra-abdominal pressure. This may be produced by growths within the abdominal cavity which so distend the cavity that the movable viscera are displaced as a hernia, the accumulation of large quantities of fat in the omentum and mesentery, more frequently neglect of proper hygiene, straining at stool from obstinate constipation, lifting heavy weights, the effort to continue the same waist measurement notwithstanding an accumulation of fat. The woman, as a rule, does not understand that there must be a compensatory displacement of the viscera when she vehemently contracts her stays, and thus hopes to conceal the gradual accumulation of adipose tissue. Not infrequently the displacement is expedited by the presence of the three classes of forces mentioned.

Symptoms and Signs.—The patient, generally a woman who has given birth to one or more children, complains of a sensation of weight and pressure or dragging when standing or walking, a burning in the bladder, and a feeling that all her viscera are about to drop through the pelvis. As the condition progresses the patient recognizes that there is a pressure on the vulvar opening, and at times a protrusion which gradually becomes larger and more persistent when she is on her feet. The protrusion disappears when she lies down, and is greatly increased by straining or lifting. Neglect of the condition results in the continuous protrusion from the vulva of the greater part of the vagina and the entire uterus. The tumor, thus protruded, rubs against her legs, against the clothing, is soiled and irritated by contact with the urine, and its vitality lessened by the engorgement from interference with the circulation. Not infrequently extensive ulcers or gravity sores form, which greatly add to the discomfort. Occasionally I have seen epithelioma develop on the protruding mass. The exposure of the vagina causes its surface to become dry and hard, covered with scales of desquamating epithelium, its walls thickened

and indurated, making replacement of the organ difficult. The extensive prolapsus causes increasing disturbance of the bladder; a portion of this reservoir comes to lie below the level of the internal orifice of the urethra, and, as a consequence, is emptied only when the protruding portion is pushed back. The retained urine soon undergoes ammoniacal decomposition, producing cystitis, increased formation of mucus, and deposits of the urine salts, which often result in the formation of calculi. I had under observation for a considerable length of time a patient who, unwilling to submit to operative interference, had a calculus form in such a sulcus every six months.

Diagnosis.—Women regard every protrusion from the vulva as falling of the womb, and in the majority of cases this will be correct. If the patient is placed in the dorsal position and directed to strain, the protrusion can be recognized, and its position will determine its character. If the protrusion is rounded, smooth, continuous with the line of the urethra, and with or without the cervix and os at its most dependent portion, it is denominated a cystocele. The finger introduced into the vagina passes behind the protruding mass. When accompanied by the cervix, the condition is generally associated with hypertrophic elongation of the supravaginal portion of the cervix. The protruding tumor in some cases may be seen to involve the posterior vaginal wall, and is continuous with the posterior vulvar commissure, when this still exists, and is known as a rectocele. Both the rectocele and the cystocele may coexist, and when associated with the presence of the uterus, the condition may be known as vagino-uterine prolapse. Occasionally the protrusion from the vulva is a more or less enlarged cervix. When examination discloses that the cervix is not elongated, but that the protruding mass is the uterus, the condition becomes a uterovaginal prolapse. If, on the other hand, the protrusion is found to be an elongation of the intravaginal portion of the cervix, and the body of the organ is but slightly, if any, displaced, it is called a pseudoprolapsus. The visual appearance of the latter does not differ from that of prolapse of the second degree. The existence of prolapsus of the third degree is determined by grasping the protruding tumor between the thumb and fingers of one hand, or placing the fingers of one hand behind the mass, and pressing against the neck of the tumor with the fingers of the other. In the procedure the uterus in complete prolapse will be within the hand in the first instance, and below the fingers in the other. In both instances the round cord of the elongated cervix will be felt to roll between the fingers in incomplete prolapse. Complete prolapse is known as procidentia. Inversion of the uterus, fibroid polypi, and tumors of the vagina are sometimes mistaken for prolapsus, but a careful examination by the introduction of one or two fingers in the vagina and the hand over the abdomen should leave no question as to the exact condition present.

Treatment.—The treatment of prolapsus may be prophylactic, mechanic, and operative. The prophylactic consists in the correction

of the conditions productive of the lesion, and in some cases must, to a certain extent, be operative. It involves the immediate or early repair of lacerations of the cervix, vagina, and perineum, if injured during labor; the regulation of the bowels and the avoidance of causes productive of severe downward pressure, as lifting and straining, proper regulation of the clothing in order to decrease the intra-abdominal pressure, and the correction of uterine displacement, especially the retrodisplacements. The mechanic treatment consists in replacing the organ and the employment of measures to prevent the return of the displacement. The instrument most frequently employed is some form of pessary, which acts either by so distending the vagina that the instrument is supported by the lower vaginal structures, or, where these are insufficient, some external support in the form of a stem secured to a belt about the waist. Where the pelvic floor is destroyed or vagino-uterine prolapsus exists, the external support is the only one which can be retained. The pessary with external support is always a source of irritation both at the vulva and the cervix, while the rubber tubes or bands become foul and produce a certain amount of disagreeable odor. Pessaries, whether ring, disc, hard rubber, or glass ball, or the variously curved instruments, are often worn for years and serve the purpose of rendering comfortable patients otherwise unfavorable for operation or unwilling to submit to such a procedure. After the instrument is worn for a time it produces an irritation of the vaginal wall which leads to a chronic inflammation of the structures and contraction, which serves to retain the organ in place, especially after the reduction in its size following the maintenance in a higher position. At other times the increased secretion causes a deposit of the salts on the surface of the pessary, which roughens it and leads to ulceration and the formation of granulations. The irritation thus produced will not infrequently lead to a pessary becoming embedded in the vaginal walls. When pessaries were frequently employed, it was a not unusual experience to be required to remove a pessary that had been worn for years and had produced so much contraction that it was difficult to displace it. Care had to be exercised in the use of instruments to prevent the glass-ball pessary from being broken. The breaking of such a pessary has led to puncture of the bladder by the fragments and the production of a vesicovaginal fistula. When the late Dr. Levis had this accident occur, he filled the vagina with plaster-of-Paris, and when the plaster had completely hardened, enveloping the glass fragments, he then delivered the mass without injury to his patient. I have delivered several such pessaries by carrying two fingers of one hand into the rectum over the pessary, by which it was crowded against the outlet of the vagina, while the latter was stretched with the remaining fingers until the pessary was delivered. The pessary is to-day rarely used—so rarely, indeed, that the profession does not realize its possibilities. When it is worn, the patient should have an occasional examination to see that the instrument is doing no injury. While

it is important to keep the parts clean, the vagina should not be irrigated with solutions of the mineral astringents, for fear of the material being deposited on the surface of the pessary and thus making it a source of irritation.

Operative Treatment.—The operative measures for the relief of prolapsus must be based on the causes of the displacement; hence the first consideration is the decrease of the size of the organ. If the seat of chronic inflammation, the uterus is curetted, a long or inflamed cervix is amputated, and the cervical and vaginal mucosa united to prevent stenosis of the canal. If the cervix has undergone elongation of its supravaginal portion, the bladder should be dissected away from the cervix to the peritoneum or above it, and a good part of the cervix amputated, after which the bladder should be attached to the uterus above the neck. The anterior vaginal wall should be resected transversely for the space of 2 or 3 cm. in the center of the protrusion, thus removing an elliptic section, extending from just behind the urethra to the upper border of the vagina. The first suture is introduced from the mucous surface of the upper edge of the vagina, then through the edge of the cervical mucosa back through it, 5 cm. from the point where it emerged, and then through the upper edge of the vaginal section again, on the right; the tying of this suture unites the vaginal and cervical mucosa; sutures are then inserted in the anterior lip on either side of this anchor suture, the posterior flaps are united, and then the lateral angles are closed. The next step is to close the edges of the resected surface on the anterior wall, each suture gathering up a portion of the bladder to guard against dead spaces and to raise up the bladder. Where the woman has passed the climacteric, this operation can be modified by opening through the vesico-uterine peritoneum, and, after drawing down the fundus, suture the vesical portion of the peritoneum to the fundus, or even to its posterior surface. When the fundus uteri is pushed back, it holds up the bladder and is itself prevented from reassuming a retroverted position. Such

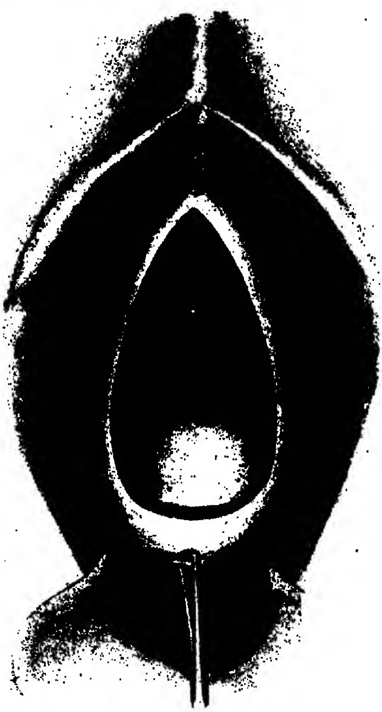


FIG. 155.—PROLAPSUS. ANTERIOR COLPORRHAPHY.

a procedure would be reprehensible prior to the climacteric, as the position and fixation of the uterus would greatly complicate a subsequent gestation and labor. The measures so far advised only in part restore the desired support. The next step is the restoration of the posterior segment of the pelvic floor as the support for the anterior. Beginning at the remnant of the caruncula myrtiformes on the left side, an incision is carried around the vulva at the junction of the

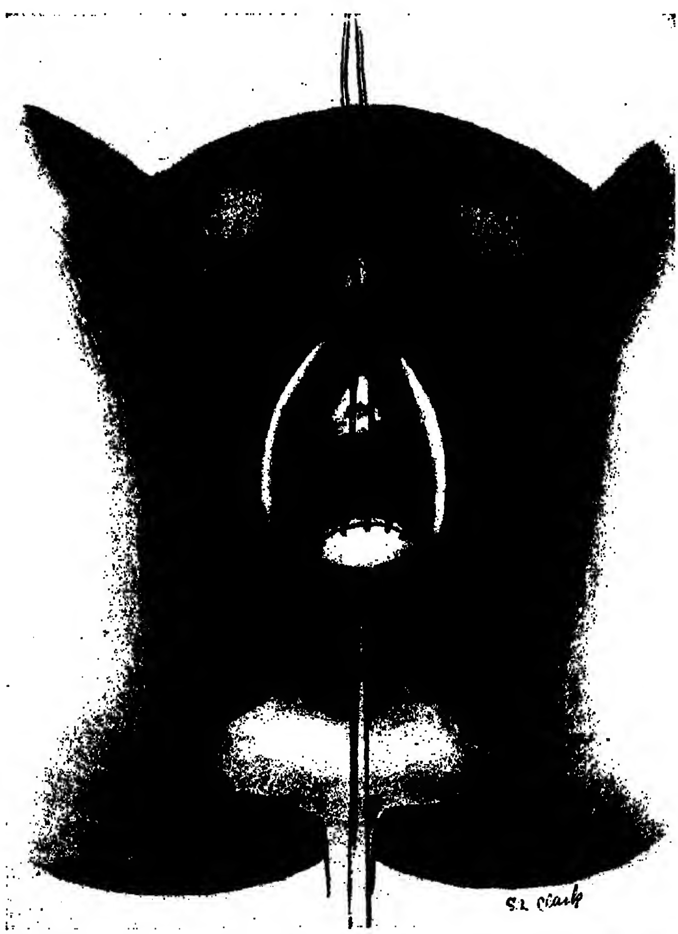


FIG. 156.—FUNDUS DRAWN FORWARD AND PERITONEUM OF BLADDER SUTURED BEHIND IT.

vaginal mucous membrane with the skin, to a point opposite on the right side. An opening is made between the vagina and rectum until it has been carried to a point corresponding to the summit of the posterior eversion of the vagina. This flap is held while sutures are introduced beneath it, picking up the levator ani muscle on each side and drawing them to the median line. These sutures also pick up the rectal wall and the inner surface of the anterior or vaginal flap,

and, after they are tied, the edges of the wound are united by a continuous catgut suture which completely buries the previous sutures.

The operation completed has narrowed the vagina from side to side, and brought together in front of the rectum a good layer of the levator ani muscles, and thus insured a good muscular floor. Where this operation has been performed as described, for the majority of the patients who have passed the climacteric nothing more need be done, but in some cases the intra-abdominal pressure is not sufficiently antagonized, and it is necessary to open the abdomen and shorten the

FIG. 157.—HYSTERECTOMY IN PROLAPSUS, WITH OUTLINE OF INCISION IN ANTERIOR VAGINAL WALL.

ligaments to secure the patient from the redevelopment of the condition. The round ligaments may be shortened, or the operation of ventrosuspension be done, both of which will be described later. Where marked prolapsus has existed, this operation results sooner or later in the uterus dragging from its anchorage, be it the ligaments or an artificial one constructed by the suspension or even fixation. In such cases it is wiser to anchor the cervix by dragging up the posterior uterine pouch and suturing its peritoneal surface, and thus draw the cervix upward and backward. When it can be

done, it is better to retain the uterus in prolapse and utilize it to prevent subsequent hernia through the vaginal canal. I have seen just as large protrusions from the vagina subsequent to hysterectomy as when the uterus formed the principal part of the mass. Numerous cases will occur, however, in which, because of suspicion of malignancy, the presence of gravity sores, extensive hypertrophy and laceration of the cervix, the removal of the uterus will be properly considered the wiser course. The operation is performed as follows: Beginning behind the urethra, an elliptic incision is carried over each side of the front of the vagina and around the cervix. The flap thus outlined is dissected from the anterior wall of the vagina, exposing the bladder; the latter is separated from the cervix to the peritoneal reflection. The lower part of the broad ligament is separated from the cervix, and the uterine arteries, if severed, are clamped and ligated. A suture ligature is inserted into each side of the vagina nearest to the point where the latter was separated from the anterior portion of the cervix and secured by a clamp forceps. The anterior peritoneum is opened and the fundus uteri brought through the opening. Where possible, the ovary and tube are included on each side, and the ligament ligated above the appendages, after which a clamp forceps is applied above the ligature. The ligature thus inserted and tied secures the ovarian artery on either side. The remaining portion of the ligament is cut, keeping watch for bleeding vessels. The edges of the peritoneum and the posterior wall of the vagina are united by sutures. At the point of the temporary suture on the left side of the vagina a suture is carried through the vaginal flap, picks up the peritoneum, passes back through it 5 cm. to the right, and is brought out through the right flap at the site of the other temporary suture and tied, while the peritoneum is joined to the vagina by sutures on either side of this suture. At the left angle of the vagina a suture is carried through both the vaginal and peritoneal structures, the broad ligament held down by forceps,

FIG. 158.—METHOD OF CLOSING THE WOUND. FORMATION OF ANTERIOR WALL, PERINEUM SECURED TO THE VAGINAL MUCOUS MEMBRANE, PERITONEAL CAVITY CLOSED BY PURSE-STRING SUTURE.

and through the posterior folds of peritoneum and the vaginal wall. A similar suture is carried through the structures on the right side, and both are tied. While traction is made on the stumps and sutures uniting the vaginal and peritoneal surfaces, the opening is encircled by a purse-string suture carried around the peritoneal surface, and, when tied, the peritoneal cavity is closed. The ligatures and sutures are all cut short, and the vaginal walls closed over the bladder in front. The vagina is packed with iodoform gauze, and the pelvic floor restored, as in the operation described for prolapsus uteri where the organ is retained. By the method of operating all the sutures and ligatures are placed outside the peritoneal cavity, and the vagina is so secured to the upper part of the broad ligaments that it cannot be prolapsed and shortened. The procedure affords the greatest protection against subsequent hernia through the vagina. In the performance of the operation twenty-day chromic catgut is used throughout for both ligatures and sutures. The result is that there are no sutures to be removed, and the patient is spared the worry and discomfort of their removal, which often causes more discomfort than the operation itself.

Dislocations of the uterus may be anterior, posterior, and lateral, and are the result of inflammation. In the development of the inflammatory process there is thrown out a large quantity of exudate, which presses the uterus to one side or in the opposite direction, but later, as this collection is absorbed and the cellular tissue undergoes contraction characteristic of scar tissue, the uterus is drawn in the direction of the former inflammatory collection and rigidly held there. When the inflammation has been in the upper part of the broad ligament on the one side, and in the lower, on the other, the organ becomes fixed across the pelvis; if, in addition, one of the uterosacral ligaments has been involved, there is a torsion, as well as the fixation, above mentioned. This form of displacement has little significance from the surgical standpoint.

The uterus may be rotated on a transverse axis either forward or backward, or on an anteroposterior axis to the one or the other side. Such displacements are known as versions.

Anteversion is a displacement of the uterus in which the fundus lies forward and sometimes downward, and the cervix backward and upward. It may be the result of chronic inflammation of the uterus and of any condition which causes increased weight. The organ may be freely movable or fixed by adhesions, or the presence of exudate in the cellular tissue about it. The thickening and enlargement generally cause an obliteration of the normal flexion. The condition may be associated with inflammation of the uterosacral ligaments. The latter are usually associated with anteflexion, but when the uterine walls are rigid from inflammation, it causes the cervix to be drawn up and increases the version.

Symptoms.—There are no symptoms characteristic of the displacement, but rather those of conditions producing it. Where the

uterus is fixed by inflammation, more or less frequency of micturition is likely to be present, and I have seen in some cases a boring pain in the symphysis which is at once relieved by the employment of measures to elevate the uterus.

Diagnosis.—The history is unlikely to indicate anything further than that the patient has some pelvic trouble. The bimanual examination discloses the cervix high in the vagina, and the resisting body, continuous with it in front, the body and fundus nearer to the symphysis than is normally found. This examination reveals the amount of fixation and inflammatory infiltrate with which the uterus is sometimes embedded.

Treatment.—The introduction of a retroversion pessary by holding the uterus at a higher level, paradoxic as it may seem to increase the displacement, affords relief. An abdominal belt, by reducing the intra-abdominal pressure, adds to the patient's comfort.

Anteflexion.—Flexion differs from version in that the uterus is bent on its own axis, and in the form under consideration the fundus lies forward, while the cervix is more or less in the axis of the vagina. The flexion may be slight, but little more than normal, or very acute, in which the body and cervix seem to lie in contact. The anterior wall at the point of marked flexion undergoes a substitution of connective tissue for the muscular structure, and on the posterior surface the wall is thinned. The flexion may be mobile or immobile; in the former the walls being soft and the fundus heavy; the position of the organ may change with the position of the body or the amount of distention of the adjacent organs. This condition, if unrecognized, will not infrequently lead to differences of opinion regarding the diagnosis, as one person may find the uterus anteflexed and the next retroflexed. The immobile flexion is fixed.

Etiology.—Anteflexion is less frequent in the parous woman than the retrodisplacements. It is more frequent than any other displacement in the unmarried and the nulliparous. The condition is congenital when the organ retains its infantile character, with a long cervix occupying the axis of the vagina, the fundus being of necessity bent forward. Inflammation of the uterosacral ligaments or of the cellular tissue posterior to the cervix, by dragging the latter upward and backward, produces a flexion of the upper part of the cervix. Growths in the fundus or upper portion of the posterior wall produce bending forward, as does inflammation of the site of the placenta in the posterior wall. Here the involution is more rapid in the uninflamed anterior wall, which acts as the string to the bow, bending the uterus forward.

Symptoms.—Anteflexion, unless accompanied by inflammation, does not cause symptoms. Those most frequently ascribed to this displacement are dysmenorrhea and sterility, but not infrequently in marked flexion neither of these symptoms is present. The existence of the displacement renders drainage defective, and thus favors the occurrence of infective processes. The extension of inflammation

from the uterus to the adjacent bladder is the cause of irritable bladder, frequent micturition, and discomfort in the evacuation.

Diagnosis.—This form of displacement is readily recognized by bimanual palpation. The cervix occupies the axis of the vagina, or may project slightly forward, while a distinct angle is recognized between it and a mass in front, which, from its contour and size, is recognized as the body of the uterus. By pressing the fingers in the vagina against the lateral portions of the uterus, the continuation of the cervix with the body can be readily appreciated, and with two fingers in the vagina against the fundus and the other against the cervix, while pressure is made from above with the external hand, the amount of resistance of the flexion is determined and the condition made certain. If there should be any doubt as to whether the mass is a fibroid growth in the anterior portion or the fundus of a flexed uterus, the procedure just described will resolve it.

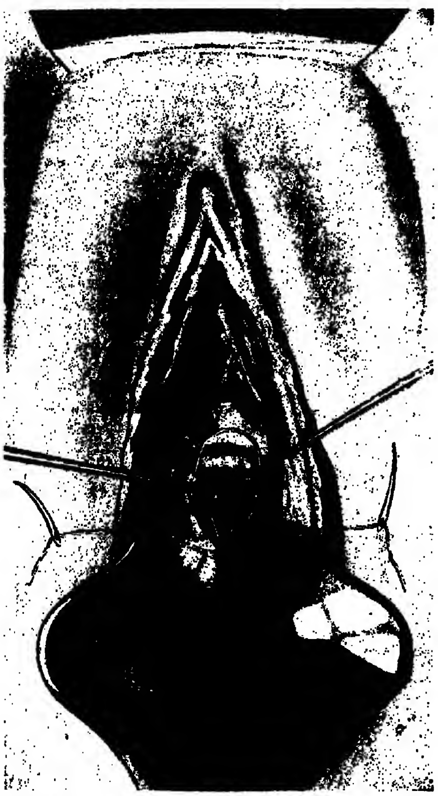


FIG. 159.—DUDLEY'S OPERATION FOR ANTEFLEXION. (Montgomery.)

Treatment.—Anteflexion requires treatment only when it is complicated, and consequently produces symptoms. It is a very frequent custom to dilate and curette the uterus for this form of displacement, and in the milder cases it may be efficient, but the more severe cases will be relieved for only a short time. I think it better that the procedure should be followed by packing the uterus with iodoform gauze; this maintains the canal in a straighter line, and the resulting inflammation serves to stiffen the walls and insure a partial obliteration of the angle of flexion. On the same principle the hard-rubber or glass drainage-tube devised by Wylie affords relief. Of a number of operative procedures, that devised by E. C. Dudley seems most worthy of employment (Fig. 159).

Dudley's Operation in Anteflexion.—After the uterus is curetted the cervix on either side is seized with a double tenaculum, and the posterior lip split to the attachment of the vagina; from each side of this incision a wedge-shaped section is removed, and the external margin, or that portion nearest the os on each side, is sutured to the

bottom of the incision. This procedure forms a new os at a higher level, and the cervix may be thrown still further back by removing a section transversely across the anterior lip and uniting the edges by transverse sutures (Fig. 160). When the conditions are favorable for pregnancy and it occurs, the termination of the pregnancy generally cures the condition. The cases should be carefully studied before being subjected to operation, for rheumatic and gouty conditions are not infrequently the cause of severe dysmenorrhea and surgical interference either is ineffective or aggravates the condition.

Retroversion.—The backward displacements are more common in women who have given birth to children. In retroversion the fundus is situated backward, while the cervix is directed forward against the bladder. The extent of the displacement may vary by a slight variation with the uterus in the axis of the vagina, or directed forward toward the symphysis, and the fundus deep in the pelvis. Retroversion is considered the first stage of prolapsus.

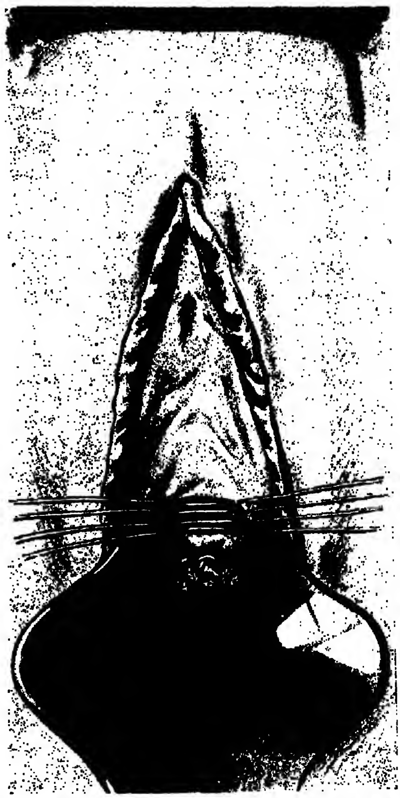


FIG. 160.—DUDLEY'S OPERATION FOR ANTEFLEXION COMPLETED. (Montgomery.)

Etiology.—The most frequent cause of this displacement is some lesion or sequel of pregnancy, although it may occur in the unmarried. Relaxation of the uterine ligaments, particularly the uterosacral, is a prolific factor, and is produced by neglect of proper hygiene, such as the regular evacuation of the bowels, permitting the bladder to become greatly distended, and improper dress. Tight lacing is the most frequent cause; the organ may be pushed out of place, and intra-abdominal pressure being directed against the anterior surface, still further aggravates the displacement. It may occur by falling from a height and striking on the buttocks, particularly if the uterus at the time be pushed back by a distended bladder.

Symptoms.—Here, as in most of the other displacements, the symptoms are those of the complicating conditions. These produce a sensation of weight, pressure, and dragging, not infrequently a feeling that all the pelvic viscera are going to drop out. Menstruation is disturbed; the flow is increased and prolonged; frequently there is

an irregular bloody discharge during the intervals of menstruation, and generally an increase of leukorrheal discharge. The projection of the cervix against the bladder causes vesical distress and frequent micturition. The pressure of the body of a heavy uterus on the rectum causes congestion of the anal vessels, the occurrence of constipation, the formation of hemorrhoids, and not infrequently the development of a fissure of the anus. No woman should be subjected to operative interference on the rectum without careful examination of the size and situation of the uterus.

Diagnosis.—The cervix will be in the axis of the vagina or directed forward, and the finger passing backward remains in contact with the posterior surface of the uterus through the vagina, while the pressure discloses the absence of the uterus in the anterior vaginal fornix. The finger in the rectum may be passed over the fundus and palpate the anterior uterine surface.

Retroflexion.—This form of flexion is very frequently a sequel of version, the uterus being retroverted, the cervix somewhat fixed, and the body driven down by the intra-abdominal pressure. It also results from metritis, inflammation of cellular tissue in front of the cervix, and inflammation of the site of the placenta on the anterior wall of the uterus. The cervix is generally in the axis of the vagina, and the extent of the flexion may vary from a slight bending backward to a complete or acute angle between the cervix and body. The flexion may be mobile or immobile; the latter may be fixed by extensive adhesions in the adjacent peritoneum.

Symptoms.—When uncomplicated, retroflexion may present no symptoms, but the interference with the circulation favors the development of infectious processes. With the onset of inflammatory complications the patient experiences a sensation of weight, dragging, and pressure on the anus. Not infrequently the pain and discomfort in the anus are so marked that the patient is led to believe that the anal condition is the important lesion. Hemorrhoids, fissures, and irritation are frequently associated with the displacement. Occasionally there will be points of anesthesia over the thighs and an uncomfortable sensation down the posterior surface of the lower extremities. Rarely, locomotor ataxia is so closely simulated as to cause that disease to be diagnosed by careful neurologists, and the fallacy is dispelled only by the entire recovery of a patient after the restoration and maintenance of the uterus in its normal position. The pressure of a large uterus on the rectum may cause obstinate constipation and produce the sensation that the intestine is obstructed. Menstruation may be variously disturbed, irregular, and profuse, the periods being either prolonged or shortened, and the intervals shortened. Leukorrhea is generally profuse.

Diagnosis.—Bimanual examination reveals the uterus at a lower level, with the cervix in the axis of the vagina or a little in front of it, and, as the fingers pass back toward the rectum, a rounded mass is discovered, between which and the cervix there is a more or less

well-marked angle. The organ may be movable or fixed. In the former, between the manipulation of the two hands, the mass can be distinctly outlined, and the condition accurately recognized, but when fixed, and especially in the presence of considerable exudation, it may be exceedingly difficult to ascertain the position of the uterus. The conditions which may be mistaken for retroflexion are a subperitoneal fibroid tumor in the posterior wall of the uterus, an ovarian growth adherent in the retro-uterine pouch, and the presence of an inflammatory exudate. The displacement can generally be differentiated from the fibroid by the shape and size of the latter and the recognition of the fundus anteriorly when the latter is present. Examination by the introduction of a finger in the rectum will be of advantage in all these cases, and should be regularly employed. It frequently must be practised with the greatest care, because of the existence of hemorrhoids or fissures, which make it exceedingly painful. In ovarian tumors, the majority of which are cystic, the sensation of fluctuation, or at least elasticity, is so likely to be present that it at once affords the suspicion of its true character. This is confirmed by more careful manipulation, which will disclose that the uterus is adherent to the growth and is not a part of it. In inflammatory exudate the mass is more or less irregular and involves the rectum and the surrounding structures. It may be so extensive as to envelop the fundus and render uncertain its position, but in such cases the diagnosis of displacement is of secondary consideration. The examination is frequently rendered difficult by an abdomen so rigid from pain or fear of it that she will not coöperate with the physician and relax her muscles. In such cases it may be well to employ an anesthetic.

Treatment of Retrodisplacements.—As the treatment of retroversion and retroflexion are very similar, in order to prevent repetition I prefer to consider them together. It has been asserted that displacements do not of themselves give rise to symptoms, from which one would naturally infer that all that would be necessary would be to treat the complication and the patient would be relieved, but experience has demonstrated that the displacement must be corrected or the distress engendered by the complication will not be dispelled. The treatment may be considered as hygienic, mechanic, and surgical.

The hygienic treatment consists in the regulation of the bowels, the removal of causes for increased intra-abdominal pressure, such as tight lacing, the weight of skirts about the waist, and the lifting of heavy weights. Such patients should be advised to avoid the dorsal position and to assume the genupectoral position for ten or fifteen minutes before going to bed, and during this time have the vulva open to the entrance of air, so that the atmospheric pressure will carry the womb upward. This can readily be accomplished by inserting the nozzle of a syringe into the vagina. When she lies down, she should lie on the side, or, better, in the semiprone position, with the under

leg extended and the upper flexed and carried forward. These measures are of value in the treatment by mechanic measures.

The latter comprise the employment of measures to maintain the uterus in its proper place by tampons and pessaries. As a preliminary to any effective treatment the displaced organ must first be placed in proper position. The pessary is only a crutch which serves to maintain the organ in its place until the forces of involution so reduce its size that its natural forces are able to maintain it. The readiness with which the organ can be replaced will depend on its mobility or immobility, whether it is free from adhesions or more or less fixed to the surrounding tissues by inflammatory bands. The mobile uterus is replaced in one of two methods: first and most frequent, the patient in the dorsal position with the limbs drawn up; two fingers of one hand, where its size will permit, are inserted into the vagina—one, the index, in front of the cervix; while the middle finger passes into the posterior fornix and pushes up the fundus, the first finger draws back the cervix. This combined movement tilts the fundus forward until it can be seized by the fingers of the hand over the abdomen and drawn toward the symphysis. By this procedure, after the internal fingers have displaced the fundus from beneath the promontory of the sacrum, they push the cervix backward and upward, to the external hand. Occasionally the promontory forms such a projecting angle that the fundus is certain to be caught beneath it, and seems obstinately fixed. In such cases the employment of a tenaculum by which the cervix can be drawn down while the body of the organ is pushed forward from the vagina, or, still better, by a finger in the rectum, the fundus passes from under the promontory, and then is pushed back and upward by the tenaculum. Second, the patient is placed in the genupectoral position, and the vulva opened to permit the entrance of air, by which the vagina is ballooned and the entire uterus carried upward so far as the length of the vagina will permit. It should not, however, be taken for granted that the uterus is thus easily replaced, for in the majority of cases it retains the malposition. Traction on the cervix downward and backward will render the fundus certain to fall forward unless held by adhesions.

After the uterus has been replaced by one of the methods described, it is ready for the introduction of the pessary by which it is to be kept in position. This instrument, preferably a Smith-Hodge, or some modification thereof, should be chosen with especial reference to the physical conformation of the patient. The instrument should be made to fit the patient and not the patient the instrument. It should be large enough to maintain its position without undue pressure at any point. The size can be readily determined by passing two fingers of one hand in the vagina, and carrying them behind the uterus as high as they will go without discomfort to the patient, and then indicate the inferior margin of the symphysis. One centimeter less than this measurement would afford the proper length. The width is determined by the distance the fingers can be readily separated

within the vagina. Where the displacement has existed for a length of time, the vaginal walls, both anterior and posterior, become shortened, the pessary has no purchase to maintain its position, and so is ineffective. In such cases the fornices should be reconstructed by having the patient wear a series of tampons, replaced at frequent intervals.

The pessary is inserted with its wide posterior bar parallel to the axis of the vulva, and after it has been inserted half its length, is generally rotated transversely and the finger against the posterior bar carries the instrument behind the cervix in the posterior fornix of the canal. As will readily be seen by inspection of a diagram of a pessary in correct position, the instrument supports the organ forward by drawing upward on the cervix through its pulley-like action on the posterior wall of the vagina. The pessary is not serviceable then when any adhesions exist which render its replacement difficult. It is of little service where the cervix is short, or at least that portion known as the portio vaginalis. It cannot be employed satisfactorily in the presence of laceration of the cervix, cicatrization in the vagina, and in contraction of the posterior vaginal fornix. It should not be employed in the virgin vagina. The cases in which it is most serviceable, and hence can be said to be indicated, are those in whom parturition has been recent, and the displacement the result of subinvolution, the ligaments being unable to maintain the heavy organ. In such cases it promotes resolution and permits the organ to reach a size that will enable its normal ligaments to support it. The pessary is of no service in marked retroflexion, as in such cases the fundus will probably be pushed behind the posterior bar and the flexion thus increased. Where the instrument is worn for a long time, the patient comes to feel that it is necessary to her existence, even after the uterus shows no disposition to become retroverted. Pessaries are so infrequently employed at the present time that the profession is likely to overlook the fact that in this instrument a valuable auxiliary is found for the treatment of suitable cases. In inflammatory cases, where the presence of pus can be excluded, pelvic massage, supplemented by tampons, may obviate the necessity of operative interference. Except when the condition is recent, the treatment requires long-continued practice and is associated with danger of injury to the tubes and ovaries when these orgas are embedded in the pelvic exudate.

Schultze advocated breaking up pelvic adhesions by inserting two fingers in the rectum, carrying them above the fundus, and hooking them forward, so as to drag the bowel away from the uterus, which is, at the same time, pushed up by the thumb in the vagina. This method is very effective in recent cases, but when one considers that the tubes and ovaries are also adherent and the difficulty of separating these structures without injury, when we can have the advantage of an open abdomen, it will be understood that it is unwise to undertake so blind a procedure. It seems to me apparent that the cases of retrodisplacement sufficiently annoying to demand treatment must,

in the great majority of cases, be relegated to the realm of surgery for satisfactory treatment.

The operative treatment of this class of cases has occupied the attention of gynecologists for many years, and a great variety of expedients have been devised. They comprise both vaginal and abdominal procedures, and are to some degree dependent on the age of the patient for whom the treatment is to be employed. A measure which may be accepted after the climacteric, because of the absence of

FIG. 161.—ALEXANDER OPERATION FOR SHORTENING ROUND LIGAMENTS. (Montgomery.)

danger from subsequent pregnancy, would be entirely unjustifiable prior to the menopause. The vaginal procedures were found so particularly prejudicial during and at the termination of gestation that they are now in disfavor unless as a part of the treatment of retrodisplacement complicated by prolapsus in women subsequent to the climacteric. The abdominal operations consist either in shortening of the ligaments extraperitoneally or intraperitoneally, or the construction of more or less definite artificial ligaments.

The Alexander Operation.—In the order of seniority may be cited the procedure bearing the name of Alexander, which was suggested as early as 1840 by a Frenchman named Alquie, first performed by Adams, and two months later by Alexander, who made the first report (Fig. 161). The operation requires two incisions, one on either side. An incision, 6 cm. long, is made just above and parallel to Poupart's ligament, terminating at the spine of the pubes, and extends through all the tissues to the aponeurosis of the external oblique, when the round ligaments are disclosed between the pillars of the external ring, enveloped in a mass of fatty tissue. A hook is passed beneath the ligament, by which it is raised and detached from the posterior fibers, seized by a pair of hemostatic forceps, and drawn out for from 4 cm. to 10 cm., according to the resistance. A similar procedure is followed on the opposite side, after which the ligaments are drawn upon until the fundus is brought beneath the pubes when they are secured to the pillars of the ring. Various modifications of the procedure have been devised. Edebohls splits the canal from the external to the internal ring and completes the operation as in the Bassini operation for hernia. Newman made the incision directly over the internal ring and drew out the ligament. Franklin Martin cut each ligament at its external end, and carried one ligament across beneath the superficial fascia and tied it to the opposite ligament. Goldspoon stretched the internal opening to permit the introduction of the finger through it to investigate and break up adhesions. This procedure was necessarily of limited application, in that it is a more or less blind operation, and consequently applicable only to those cases in which the absence of adhesions is evident. The traction of a uterus drawn forward by shortened ligaments and backward by adhesions between it and the rectum makes the last condition of such a woman worse than the first.

Ventrosuspension and *ventrofixation* was a procedure devised by Olshausen and perfected by Kelly. The necessity for this procedure grew out of the limitations of the Alexander operation. It consisted of an incision, 4 cm. long, just above the symphysis, in the median line, through the peritoneum and all the suprajacent structures. The uterus is separated from adhesions, the ovaries and tubes inspected, and subjected to such treatment as the conditions may demand, and the uterus brought forward and secured to the peritoneum at the lower angle of the wound. The sutures are inserted into the fundus at its center, or a little back of the center, so that the anteflexion of the normal uterus is slightly increased. Generally, two sutures, about eight millimeters apart, are introduced into the fundus. When a short ligament or a direct fixation is desirable, it is the rule to push back the peritoneum and make the suturing between the muscle and the fundus of the uterus (Fig. 162). The suspension sutures were formerly buried sutures of silk, silkworm-gut, and occasionally of silver wire, but these buried sutures so frequently gave rise to irritation and suppuration during convalescence or subsequently

and always continued as an annoying sinus until the suture was either discharged or removed, that the majority of operators prefer to use an absorbable ligature.

The operation has a number of disadvantages: It places the organ in an abnormal position, and maintains it at best by a cicatricial ligament which may stretch but never subsequently contracts; it is impossible to determine in advance whether the operation will result in a fixation or a suspension; in the latter case, it may become so elongated that it no longer exerts any beneficial influence. It forms an artificial obstruction within the abdominal cavity, about

FIG. 162.—VENTROSUSPENSION FOR RETRODISPLACEMENT. (Montgomery.)

which the coils of intestine may become twisted, leading to fatal results, as occurred in one of my cases and in the experience of other operators. When the band is strong, it may prove a source of discomfort in a subsequent gestation and be a cause of dystocia in labor. When it elongates, the band becomes so stretched as no longer to exert a beneficial influence, and the original condition is reproduced.

Intraperitoneal shortening of the ligaments has been performed in a number of ways, as the doubling of the ligaments inward (Wylie) or outward (Baer), folding them on themselves (Mann), drawing a loop through a slit in the anterior wall (Ries), securing a loop to the anterior wall (Dudley), penetrating the broad ligament with a loop which was secured on the posterior wall (Webster), cutting the ligament near the uterus, ligating the proximal and carrying the distal end through the broad ligament to be secured posteriorly (Baldy), cutting out a section of the round ligament and the peritoneum of the broad ligament, and reuniting them (Bissell), dragging a loop of the ligament through the abdominal wall and securing it on the aponeurosis (Gilliam) modified by gathering up the peritoneal surface external to the point at which

the ligament was drawn through, with a purse-string suture (Ferguson), carrying the loop beneath the peritoneum through an incision in the anterior leaflet of the broad ligament and securing it to the under surface of the rectus (Simpson), and, finally, my own modification, which is as follows (Fig. 163):

Through a median incision, or, as I prefer, through a Pfannenstiel incision (p. 485), each round ligament is caught about 4 cm. from the uterus and secured by a temporary loop of catgut, the ends of which are threaded into the eye of a Deschamp needle. Through an opening

FIG. 163.—MONTGOMERY'S METHOD OF SHORTENING THE ROUND LIGAMENTS. (Montgomery.) Round ligament fixed with hemostat while temporary ligature is carried beneath anterior leaflet of broad ligament with a Deschamp needle.

made in the anterior leaflet of the corresponding broad ligament the needle is carried outward between the two layers of the ligament until it reaches the point where the peritoneum is reflected on to the abdominal wall, when it is carried through and unthreaded, and the ends of the ligature secured by forceps (Fig. 164). The same steps are followed on the opposite side. The ligature is then put on the stretch, a pair of sharp-pointed scissors inserted alongside it closed, and the blades slightly separated, after which a loop of the ligament is easily drawn through and is secured to the outer surface of the aponeurosis

by chromic catgut sutures. The loop is drawn through sufficiently to bring the fundus of the uterus well forward. Should it be insufficient or too much, the position of the uterus can be governed by drawing upon or relaxing the projecting loop. This procedure imitates the virtue of the Alexander operation in that it utilizes the strongest part of the round ligament, that portion nearest to the uterus, and has the advantage of its adaptation to all displacements whether complicated or uncomplicated. The operation permits the treatment of diseased conditions of the tubes and ovaries, leaves no

FIG. 164.—MONTGOMERY'S METHOD OF SHORTENING ROUND LIGAMENTS. (Montgomery.) Loop secured on the aponeurosis.

raw or injured surface within the peritoneal cavity, and provides a support capable of undergoing evolution and involution and consequently capable of meeting the future exigencies in the life of the individual.

The uterosacral ligaments have been utilized through the vagina (Gottschalk, Bovée) or through an abdominal incision. Where the retrodisplacement is associated with much prolapsus, these ligaments are generally so attenuated as not to be appreciable. In several instances I have reconstructed the retro-uterine pouch in order to

obliterate or close off its most dependent portion. This operation does not give any special consideration to the ligaments, but forms a new floor of the peritoneum. Through an abdominal incision the uterus is drawn forward and the intestines packed out of the pelvis, with the patient in the Trendelenburg position; with a double tenaculum the peritoneum is seized at a point posterior to the cervix and drawn backward; the peritoneal surfaces at this level are united, and the peritoneal covering of the bowel to that of the posterior surface of the neck of the uterus. Care must be exercised completely to close the cavity, otherwise coils of intestine would slip through, producing strangulated hernia.

Vaginal Operations.—Among the earliest vaginal procedures was that devised by Schucking, which consisted in passing an instrument to the fundus after the uterus was placed in extreme flexion, and pushing a needle concealed within it through the anterior vaginal fornix. The needle carries a ligature back, which, when tied, holds the uterus in anteflexion. It is apparent that this is a blind procedure, and injuries of the bladder and intestine have occurred.

Vaginal Fixation.—Dührssen devised an operation which was subsequently modified by Mackenrodt, whereby, through a vertical incision of the anterior vaginal wall, the bladder is pushed away from the cervix until the peritoneum is reached, when, without opening the latter, a suture is introduced and the uterus pulled forward; a second suture is introduced above this, near the fundus, which holds the uterus forward by being passed through the edges of the vaginal wound and tying it in the vagina. Mackenrodt opened the peritoneum and inserted the sutures at a higher level, but the results of these operations in subsequent gestation and parturition have been found so disastrous that they have been discontinued during the child-bearing period.

Wertheim, as well as Vineberg, utilized this incision to secure the round ligaments by passing a suture under each ligament, 3 cm. from the cornu of the uterus. The ends of the suture are brought out through the corresponding vaginal flap. After both ligaments are thus secured, the peritoneal and vaginal wounds are closed.

Inversion of the uterus is a form of displacement in which the lining membrane of the uterus becomes its covering, and, when complete, the organ is entirely within the vagina. The inversion may be partial or complete. It is usually divided into three degrees: First, *intra-uterine inversion,* which presents three degrees of displacement of the uterus into its own cavity without the cervix being dilated (Fig. 165). When the wall is partially inverted, it is known as invagination. The second degree is known as *intravaginal inversion,* when the body of the uterus to a greater or lesser degree projects through the external os (Fig. 166). *Extravaginal inversion* is the third degree, in which the uterus is partially or completely outside the vagina, and represents an inversion of the vagina as well (Fig. 167).

Inversion uteri is divided, according to its causes, into puerperal

and non-puerperal, the former the result of parturition; the latter generally produced by traction of a fibroid growth attached by a short pedicle to the fundus of the uterus. As the displacement proceeds, in place of the fundus there is a funnel-shaped depression. As the tubes are closely connected with the uterus, they are to a considerable extent drawn into the cavity, while the ovaries may rest upon the rim of the funnel. The uterine mucous membrane exposed in the vagina undergoes inflammatory changes with a certan amount of epithelial desquamation. The orifice of the Fallopian tubes can generally be seen upon either cornu of the uterus, while the upper part of the tumor is surrounded by a cuff formed by the vaginal portion of the cervix. The situation may readily permit the entrance

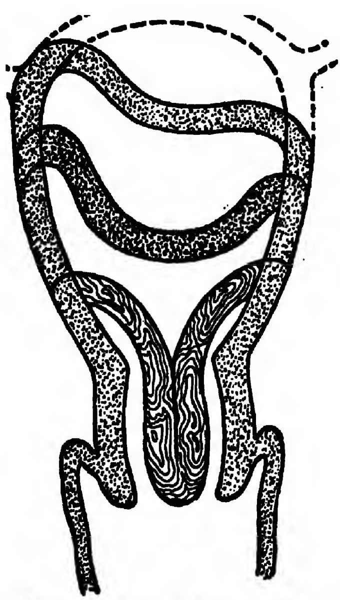


FIG. 165.—PARTIAL INVERSION, THREE DEGREES. (Montgomery.)

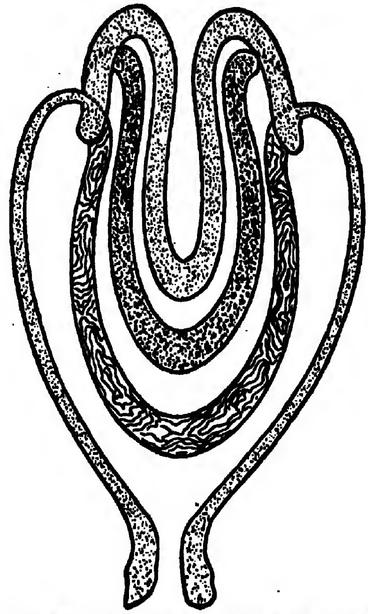


FIG. 166.—INTRAVAGINAL INVERSION, THREE DEGREES. (Montgomery.)

of infection into the tubes, causing extensive inflammation which adds to the discomfort of the patient.

Etiology.—The displacement arises as a result of a relaxed condition of the uterine walls, not infrequently produced by traction upon the cord in premature efforts at the delivery of the placenta. It is more likely to occur when the umbilical cord is short, and may be produced by overstretching of the cervix, affording less resistance to the invaginated body. In the non-puerperal variety a submucous fibroid of the sessile variety fills the body of the uterus until the cervix is partially distended; contractile efforts to expel the growth as a foreign body leads to further dilatation of the cervix and dragging downward of the fundus by the weight of the growth. This continues until the inversion becomes complete (Fig. 168).

Symptoms.—The production of the condition not infrequently leads to severe shock and very profuse hemorrhage. The patient complains of a severe pain, a sensation of pulling or fullness in the vagina. As the disorder progresses menstruation is rather prolonged, and a profuse mucous discharge irregularly tinged with blood occurs.

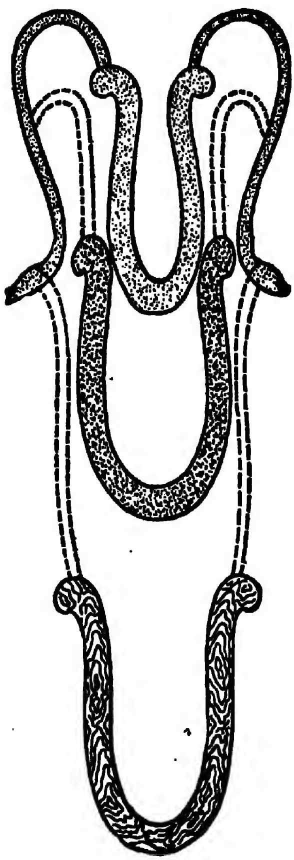


FIG. 167.—EXTRAVAGINAL INVERSION. (Montgomery.)

FIG. 168.—NON-PUERPERAL INVERSION. (Montgomery.)

Diagnosis.—The existence of severe pain, profuse bleeding, and profound shock in a woman who has undergone a rather severe labor, and following efforts at delivery of the placenta, should lead to careful investigation as to its cause. The exploration of the vagina discloses a large globular mass which fills it, surrounded by a cuff-like ring at its upper part. The hand placed over the abdomen reveals the absence of the fundus of the uterus, and, instead, a funnel-shaped depression at the upper part of the pelvis. A rectal examination discloses the funnel-shaped depression in place of the uterine fundus. Examination by the speculum reveals the vagina filled with a mass covered with soft and velvety mucous membrane, possibly points of ulceration,

and in the early stages small clots. Where the patient has thick abdominal walls, it may be difficult to determine the physical signs.

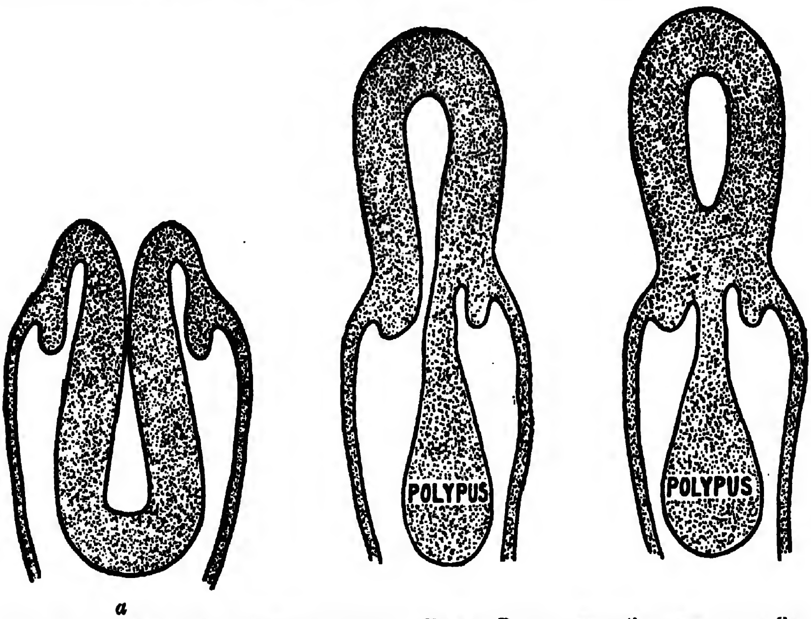


FIG. 169.—*a*, INVERSION; *b*, FIBROID POLYPUS; *c*, FIBROID POLYPUS WITH STENOSIS OF THE CERVICAL CANAL. (Montgomery.)

Inversion may be confounded with fibroid polypus, submucous fibroid, and partial division of the fundus uteri. The fibroid polypus

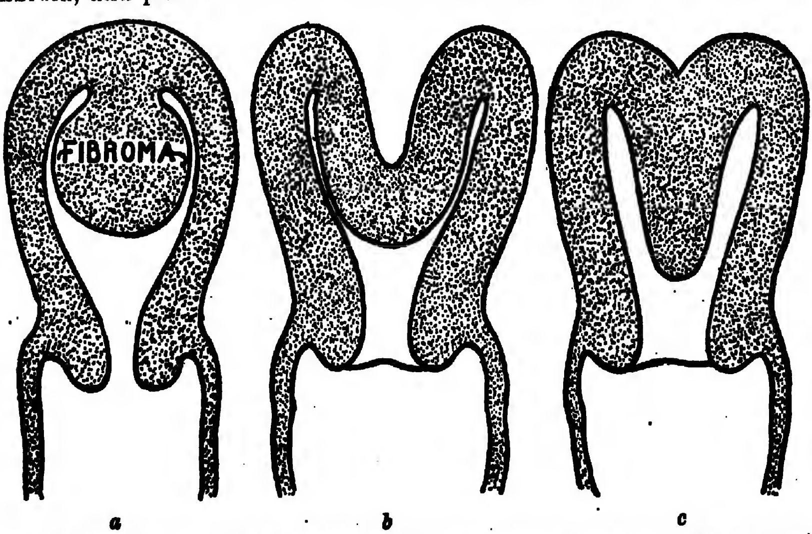


FIG. 170.—*a*, FIBROMA; *b*, PARTIAL INVERSION; *c*, PARTIAL DIVISION OF THE BODY. (Montgomery.)

projecting into the vagina surrounded by the cervix may present a state so characteristic of inversion as to cause its true nature to be

overlooked (Fig. 169). A number of cases have been reported in which efforts have been made to reinvert such a growth, when subsequent investigation has disclosed it not to be a uterine inversion. Careful bimanual examination will reveal the fundus of the uterus within the abdominal cavity, while the mass is situated below; while in inversion, the fundus has disappeared and the funnel-shaped cavity in its place can readily be determined by investigation through the rectum (Fig. 170). A fibroid growth within the cavity of the uterus may simulate the first degree of inversion, but here too the rectal examination reveals the funnel-shaped depression in the inversion

FIG. 171.—CENTRAL TAXIS. (Montgomery.)

and a globular mass in the submucous fibroid. Partial division of the body of the uterus is recognized by the anteroposterior depression between the two cornu, while in inversion the depression is circular.

Treatment.—Treatment for inversion depends upon the form under consideration and the stage at which it comes under observation. It differs very greatly in the recent from that of the chronic cases. Treatment may be manual, instrumental, and operative. In the recent inversion, placing the fingers against the body of the uterus, and pushing upward may readily lead to the reinversion of the organ with the hand situated within its cavity. This method of procedure

should always be practised when it is recognized that the lesion has just developed. In some cases, placing the patient in the genu-pectoral position with the vagina dilated causes reinversion. The manual treatment consists in the application of what is known as taxis, by the employment of the hand in the vagina (Fig. 171). This may be applied in three ways: First, central taxis, in which the thumb or finger is placed against the fundus of the uterus and pressure is made upward. This can be antagonized by placing the other hand

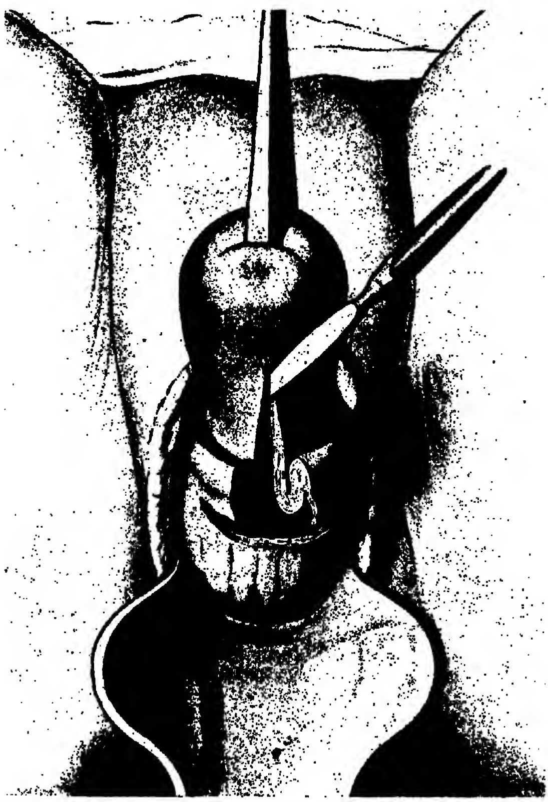


FIG. 172.—INCISION OF THE POSTERIOR VAGINAL FORNIX AND THE NECK OF THE UTERUS PRELIMINARY TO REDUCTION. (Montgomery.)

over the abdomen and spreading out the funnel opening. Lateral taxis is the introduction of the hand into the vagina; while the fingers grasp the fundus, the thumb presses against a cornu of the uterus, and this is continued until the process of reinversion is completed. Peripheral taxis consists in the introduction of the hand into the vagina, and spreading the fingers around the cervix, making traction upon the cervix through the vaginal walls, thus opening the cervix while the fundus is pushed upward. Taxis has been applied by instrumental measures, as an instrument having a spring arranged as a cup which fits over the fundus and presses it upward. This has

been supplemented by Marcy, who inserted sutures into the neck of the uterus and tied these over an elastic mass pressing against the fundus, so that the pressure was continual. Tampons and colpeurynters have been introduced into the vagina with a view to making more or less pressure upon the uterus and thus gradually overcoming the displacement. Among the earliest procedures was one instituted by Thomas, who opened the abdomen and with an instrument similar to a glove-stretcher enlarged the cervix, while pressure was made from within the vagina against the fundus. The most effective method is that instituted by Küstner, who made an incision through the posterior fornix of the vagina above the cervix and then a vertical incision through the neck, when the fundus was pushed up (Fig. 172). In a recent case I first drew down the uterus, inserted suture ligatures through the cuff of the cervix,—two in front and one on either side,—and then made an incision, as suggested by Küstner, when I found that it was very easy to reinvert the uterus. The fundus was turned down through the incision in the posterior wall of the vagina, and the incision sutured with chromic catgut. After the incision of the uterine wall had been completely closed, the opening in the posterior fornix of the vagina was sutured, and iodoform gauze packed into the vagina, holding the uterus up. The uterine wall becomes so rigid in a short time after this occurrence as a result of inflammatory changes that the subsequent manipulation by taxis to accomplish the reinversion is attended with possibilities of such serious injury to the structure of the uterus that it seems to me far preferable to at once institute the procedure described as less likely to result in trauma.

Tumors.—Tumors of the uterus are divided according to their origin into connective-tissue and epithelial growths. The course of the tumor leads to a further division into benign and malignant. Benign growths are those which are limited to the organ in which they originate, even though it may be more or less destroyed and taken up as the growth develops. The malignant show a constant tendency to break down their barriers and to invade the surrounding structure. They are destructive not only of the tissue invaded, but of the life of the individual, and, when removed, exhibit a marked tendency to recur. It is sometimes difficult to differentiate between these two classes of tumors, as a number of those which are regarded as benign betray a disposition to recur, and subsequently to assume malignant characteristics. The benign tumors of the uterus are represented to a large degree by the fibromata, the pathology of which can be found in Vol. I, p. 771, of this work. They are designated myomata and fibromata, according to the relative amounts of muscular and fibrous tissue of which they are composed. They are the most frequent of uterine growths, and occur in the majority of women who have passed the thirty-fifth year of life. Their period of greatest growth is during the menstrual life of the individual, although they rarely appear before the twenty-fifth year, and were formerly supposed

to have attained their complete growth prior to the occurrence of the menopause. Later investigations have shown that these growths not infrequently continue to increase in size subsequently to the climacteric, and one case has been reported in which a growth of considerable size developed in a childless woman who had never menstruated. They rarely occur alone, but are more frequently multiple. Bland-Sutton reports a case in which there were 120, varying from a pea size to that of a small orange. Not infrequently a uterus which is studded with these growths when hardened and sectioned presents a tessellated appearance, in which but little of the uterine structure remains. Where a large number of the tumors exist, they are usually small. Hunter reports a uterus containing fibroids in which the entire mass weighed 145 pounds. As we have seen, this class of tumors is divided into the myomata, in which the growths are made up mostly of muscular structure of the uterus and present but little differentiation from the organ. In these, the tumor rapidly increases and attains not infrequently to an enormous size. The fibromata, on the other hand, are growths which have reached a certain degree of maturity and there has been an increase of the fibrous or connective tissue over the muscular structure. They are hard, firm, generally surrounded with more or less of a capsule, which consists of loose connective tissue and blood-vessels.

Tumors are divided according to their relation to the wall of the uterus into submucous, interstitial, and subperitoneal. Submucous fibroids, also called intramural and concentric, are those which are situated more closely beneath the mucous membrane, and, as they increase in size, have encroached upon the uterine cavity. They are divided into the encapsulated and the non-encapsulated. The former are surrounded by a loose layer of connective tissue, making a distinct capsule, which will permit the tumor to be shelled out of its bed. The non-encapsulated, however, have the mucous membrane of the uterine cavity directly enveloping the growth without any intervening capsule. These growths may have developed beneath the mucous membrane and have been pushed out, thus making them free from the capsule, or were originally encapsulated, but their capsule has disappeared during subsequent inflammation. As the tumor is extruded into the cavity of the uterus and becomes more and more separated from the uterine wall, it may be attached by a more or less thickened band or pedicle, when it is known as a pedunculated tumor or a polypus. In other cases the tumor is attached to the uterine wall by a broad base. These tumors are called sessile fibroids.

The presence of the tumor leads to more or less of congestion and inflammation of the uterine structure, so that, as it increases in size, there is an effort upon the part of the uterus to extrude it as a foreign body. This expulsion produces its polypoid character. When the mass is situated near the fundus and is of considerable size, the efforts at its expulsion may lead to dilatation of the cervix and to dragging

of the tumor upon the fundus, producing inversion. As the cervix becomes well dilated, this inversion may become complete. When the tumor is pedunculated and pushed partly through the cervix, the grasp of the cervix upon it brings about an interference with the circulation of the surface of the tumor, producing caries or ulceration. The irritation of the tumor as a foreign body induces an associated endometritis with a tendency to produce bleeding, so that such a growth, from the associated hemorrhage and offensive discharge, may cause the suspicion of malignant disease. Not infrequently the rapid extrusion of these growths either into the uterine cavity or externally causes complete loss of nutrition and gangrene of the mass, so that its exit in fragments is associated with thin, foul discharge.

Interstitial, mural, or centric growths are those which are developed into the central portion of the wall, and, as they increase, take up the structure of the uterus. According to their situation and size they are differentiated as circumscribed and diffuse: circumscribed, when the growth is small, well defined and possibly attended by two or three other growths. Diffuse tumors, on the other hand, are rapid in their development, spread out the structure of the uterus, and may occur as a single growth. These are the tumors which attain to the largest size, becoming gigantic masses. The entire structure of the uterus is taken up by them; its lower portion may be drawn out, forming a pedicle which may readily become twisted. In some cases the cervix has become so attenuated that the growth and the body of the uterus are separated from the cervix. As these growths increase in size they encroach upon the cavity of the uterus and produce disturbance of the endometrium, not infrequently leading to interstitial metritis and profuse bleeding.

Subperitoneal, extramural, or eccentric fibroids are those which are originally situated near to the peritoneum, and, as they increase in size, are expelled upon the external surface of the uterus and covered by the peritoneum. These tumors, like the submucous, may become pedunculated or sessile, but the former are rarely called polypoid. The surface of the tumor may be perfectly smooth, covered with a layer of peritoneum, and beneath it muscular structure. In other cases, from the increased amount of connective tissue and contraction, the tumor is roughened. These tumors, like the submucous, are free and encapsulated, the former with the peritoneum directly over the surface of the tumor, without any intervening loose connective-tissue layer. The pedicle varies greatly in size from a small fibrous band, or so short as to hold the tumor in apposition to the uterine wall to one which is sufficiently long as to leave the investigator in doubt as to whether the mass is connected with the uterus. In some cases where the growth is of considerable size with a small pedicle, the latter may become twisted and the nutrition of the tumor thus cut off. In such cases the growth may form adhesions to the surrounding viscera, through which it may receive its nutrition, when the pedicle disappears, making the tumor a parasite. The pedicle

may sometimes be so flexible as to permit the tumor to be pushed away from the abdominal wall, and come back against it, simulating ballottement. Where the nutrition of the tumor is interfered with, or in some cases where it has attained considerable size and is roughened, it so irritates the peritoneum as to cause ascites. The cervix differs from the body of the uterus in its structure to such a degree that it is rarely the site of origin of fibroid growths. Not infrequently, however, these growths are pushed downward from above, spreading out the cervix and forming a tumor so large as to fill up the vagina. These form two classes: one, pushed into the external os, and the other, the subvaginal, pushed out through the wall of the cervix, and secures a situation in the broad ligament. These growths not infrequently raise up the ureter and endanger it during the removal of the tumor. Occasionally they are situated between the bladder and the uterus.

Etiology.—Our knowledge of the cause of fibroid tumors is very slight. There are a number of hypotheses, all of which are mere guesses. By some they have been attributed to inflammation in the muscular structure of the vessels supplying the uterus, and this supposition is supposed to be confirmed by the occurrence of whorls or circular masses of connective tissue which compose the fibroid growth and the absence of distinct vessels within the growth. The growths are found with about equal frequency in married and multiparous women, and in the unmarried and nulliparous.

Symptoms.—The presence of symptoms will depend upon the variety of the tumor; thus, in the interstitial and subperitoneal, the growths attain to large size without their presence being suspected. In some forms of the interstitial and in the submucous, hemorrhage is an early symptom. As the growths increase in size, pain and abdominal cramp exist as a result of the effort on the part of the uterus to expel the developing mass, so where a patient has an increased menstrual flow or irregular bleeding, has increasing distress at each menstrual period, and attacks of severe abdominal cramp, the suspicion of the presence of a fibroid growth is justifiable. The increase in size of the tumor leads to pressure upon the surrounding viscera of the pelvis, and the earliest discomfort is experienced from the pressure upon the bladder. Urination becomes frequent, the sensation of pressure and discomfort, with inability of the bladder to become distended or to retain for any length of time its contents. Not infrequently the first symptom, on the contrary, will be an attack of severe retention. An examination discloses as its cause the presence of a fibroid growth impinging against the neck of the bladder. Not seldom the patient will complain of distress in the rectum about the anus, burning and sense of weight, discomfort from the presence of hemorrhoids and fissures. The menstrual function may be undisturbed, especially in the subperitoneal and those interstitial growths which have not encroached upon the mucosa, but in the submucous and those interstitial tumors which impinge against this membrane

disturbance of menstruation is very frequent. This may occur in the form of prolonged and profuse menstrual flow, or hemorrhage which takes place in the intermenstrual period, or of profuse bleeding alternating with amenorrhea. In addition the patient has profuse leukorrhea, due to an increased glandular secretion. This may be purulent, watery, or mixed with blood, not infrequently presenting an offensive odor. The increasing size of the tumor causes pain, which is aggravated at the menstrual period by the efforts on the part of the uterus to expel the growth. Sometimes the tumor, being pushed into the cervical canal, acts as an obstruction to menstruation, causing violent dysmenorrhea. The changes in the uterine mucosa and irritation induced by the presence of a growth are among the most prolific causes of sterility. As the growth increases in size it presses upon the rectum, producing constipation. It may produce pressure upon the ureter, leading to dilatation of the ureter, of the pelvis of the kidney, to hydronephrosis, to sacculation of the kidney, and destruction of its secreting substance. The profuse bleeding, the continuous discharge, the discomfort from pressure, and the interference with the performance of the functions of the viscera cause anemia and have an injurious effect upon the general health. These patients, however, while anemic, are not emaciated and do not show a cachexia such as is associated with malignant growths.

Diagnosis.—As has already been mentioned, the tumor may produce no symptoms and remain unsuspected by the patient until it has attained such a size as to attract the attention of others. As such tumors increase in size, however, they produce a sensation of weight and pressure, disturbance of urination, attacks of severe retention of the urine, the development of hemorrhoids, burning and pain on defecation, and not infrequently profuse bleeding. The occurrence of such symptoms, or of profuse menstrual or irregular flow, in an unmarried woman or one who has no history of the interruption of pregnancy or the occurrence of abortion associated with labor-like efforts at expulsion, with marked anemia without emaciation, should lead to the suspicion of the presence of a fibroid growth, and should be considered as ample justification for careful pelvic investigation. When the patient is examined, the tumor is recognized by its increased consistency as compared with the surrounding parts, by its well-marked and well-defined outline, by the alteration in the shape and size of the uterus, and when a number of these masses occur, they will be found to present points of induration with intervening softer spaces, the uterus will be enlarged, may be irregular, or where the mass fills out this body, may present a spheric shape. Such a mass may be partially or completely extruded into the vagina, supported by a pedicle which may be traced into the cervix. Small pedunculated intra-uterine fibroid growths may be felt to move within the uterine cavity. Where the growth is small and with a short pedicle, it may require palpation through a dilated cervix to determine its size and presence. These submucous growths are frequently extruded through

the uterus during menstruation and recede in the intervals, so that it is often wise to examine the suspected patient during menstruation.

A large growth may be impacted in the pelvis, cause pressure on the pelvic veins, induce edema of the lower extremities, or the pressure may be chiefly upon one or both ureters, and, as has been mentioned, result in dilatation of these ducts, of the pelvis of the kidney, and of hydronephrosis, not infrequently the formation of calculi and the production of conditions which favor infection and subsequent suppuration. Very infrequently it is found that fibroid growths are complicated by cardiac changes, whether a result of a condition which was productive of the fibroid growth or due to the influence of toxins produced by them. Cardiac and renal lesions not infrequently bring about edema of the extremities, the formation of thrombi producing phlegmasia, and occasionally pulmonary and cerebral emboli, which may cause the death of the patient. The pelvic examination should be performed not only to determine the presence of the tumor, but to differentiate the particular variety, whether submucous, interstitial, or subperitoneal. The subperitoneal may occupy any one of three positions. Most frequently they are extruded from the antero-posterior wall of the uterus; less frequently they form what are known as intraligamentary tumors, which are pushed out laterally from the uterus; and still less frequent are those which are pushed downward and backward from the posterior uterine wall beneath the peritoneum, but not in contact with it. In the diagnosis of fibroids they must be differentiated from normal or extra-uterine pregnancy, from fibroids of the abdominal wall, inversion of the uterus, carcinoma, sarcoma, incomplete abortion, subinvolution of the uterus with metritis, uterine displacements, ovarian cysts, pelvic exudates, and floating kidney; from pregnancy, by the existence in the latter of amenorrhea, the rapid and progressive increase in size of the uterus, the sensation of elasticity, and absence of any induration or hardness in the walls. Occasionally, however, when, as the result of some degenerative process, the tumor may become edematous, it is difficult to determine with which condition we have to deal. When the history and associated signs are insufficient to determine the diagnosis, it will be well to direct the patient to return some weeks later for another examination, when, if pregnancy exists, the changes will generally be such as to enable the diagnosis to be made. In extra-uterine pregnancy the progress of the case and the early tendency to rupture of the sac is generally sufficient to make the diagnosis clear. Fibroid tumor of the abdominal wall is a growth which occurs in the sheath of the abdominal muscles. It generally becomes dependent, dragging downward, but in rare cases, as it increases in size, it is pushed into the abdominal cavity and is covered by the parietal peritoneum. In such cases the uterus will be situated below it in the pelvis, and can be found to be movable upon it. A case of this kind came under my observation where the growth filled the abdominal cavity, was so smooth in its outline and so firmly resisting, that I had no hesitancy

in believing that I had a fibroid growth involving the uterus, and it was only when the abdominal incision entered the tumor without opening the peritoneal cavity that I realized the situation. The tumor, when removed, weighed 19 pounds. The differential diagnosis of inversion has already been given. In carcinoma the uterus is not likely to be much increased in size. The disease, in the great majority of cases, involves the cervix and is palpable. When it develops in the body, the portion of the structure affected presents a less well-marked hardness than is displayed in the fibroid growth. In sarcoma the uterus increases in size, is soft and elastic, there are profuse bleeding, offensive discharge, and marked constitutional symptoms. In incomplete abortion the history of the case and the enlargement of the uterus without any well-defined hardening, will generally excite a suspicion of its true character. In subinvolution with metritis the entire uterus is uniformly enlarged. In small fibroids within the uterine cavity it may be necessary to palpate the cavity in order to determine the presence or absence of growths. In uterine displacements the condition is determined by bimanual palpation, through which we are enabled to outline and determine the size of the uterus, and that a mass in the anterior or posterior wall is the fundus of the organ so situated from flexion. Ovarian cysts may be so closely adherent to the uterus as to be supposed a part of it, but there is generally a sensation of fluctuation, and careful investigation shows that the uterus lies against the tumor rather than is a part of it. In pelvic exudates the mass is irregular and melts off into the surrounding structures in such a way as to appear as a well-defined growth, as it would were it a fibroid. Floating kidney can rarely be mistaken for a fibroid growth. Its greater mobility and the possibility of pushing it away from the uterus are sufficient to exclude its being mistaken for such a growth.

Alterations and Degenerations.—As already stated, fibroid tumors which have been in existence for some time undergo a form of maturity in which they are surrounded by a distinct and well-defined capsule of cellular tissue, abundantly supplied with blood-vessels. The tumor itself obtains its nutrition by a process of transudation of fluids. Interference with the nutrition of the tumor, whither by the contractile efforts of the uterus to expel it or from other causes, leads to further alterations. One of the most frequent of these is the spreading apart of the structure of the tumor by the accumulation of fluid within it, the tumor becoming edematous. I have seen this occur to such an extent that the mass was supposed to be a cystic, rather than a solid, growth. Such a condition is not infrequently difficult to differentiate from pregnancy on the one hand, and, on the other, from an areolar ovarian cyst. In some cases the spreading apart of the structure of the fibroid growth becomes permanent and the tumor is really cystic. Such growths are known as fibrocystic tumors. In others, portions of the structure undergo liquefaction or a myxomatous degeneration, so that numerous spaces are filled with

a colloid material. These are known as fibromyxomata. In some cases the interference with the circulation in the tumor causes a deposit of the salts of the serum upon the surface and in the structure of the tumor. Where this exists for a length of time, the growth becomes quite hard and firm. An intra-uterine tumor of this kind may subsequently separate from the uterus and be discharged. Such an alteration has undoubtedly been the explanation of the cases in which it was supposed that an egg-like mass had been thrown off. Such changes are known as calcification. They are quite common where the growth has been carried for a long period of time.

Interference with the nutrition of the growth may result in partial loss of vitality, producing symptoms of inflammation. The inflammation generally exists around the tumor, rather than in its structure, and it will be found that the tumor is surrounded by an extensive exudate, rendering demarcation difficult, or, where it has existed for a length of time, extensive adhesions between it and the intestines or the abdominal parietes may lead to nutrition of the growth, independent of its original attachment. Where the vitality of the tumor is to a considerable degree destroyed, its powers of resistance are lessened, and its proximity to the intestines may lead to infection and suppuration. An abscess thus formed may be walled off, and the tumor, to a large extent, undergo disintegration. Such a patient suffers from all the symptoms characteristic of a septic process—elevation of temperature, recurrence of chills, and progressive emaciation. The loss of vitality may be such that the entire tumor becomes gangrenous, disintegrates, drags down, and, when intra-uterine, may be thrown off through the uterus and vagina. If situated within the abdomen, however, it becomes a foreign body. The toxins generated within the growth are absorbed, causing marked depression, often a condition of collapse, and indicate the existence of some profound disorder. Fibroid growths are not infrequently associated with malignant degeneration. The latter may be in an entirely separate portion of the uterus; thus I have seen carcinoma of the cervix with fibroid growth of the body. In other cases the degeneration exists over the entire mucous membrane of the uterus, forming an adenocarcinoma of the uterine body. It is quite possible that the increased irritation of the uterine cavity induced by the presence of the growth may be an exciting cause of the malignant disease. Occasionally it is found that a tumor is the site of sarcomatous degeneration, and this process may spread until the entire tumor has become malignant. Indeed, this complication exists with sufficient frequency to lead to the supposition that it is one of the degenerations incident to fibroid growths.

Complications.—The irritation of the fibroid growth within the uterine cavity generally leads to so much inflammation of the endometrium that the disorder known as interstitial endometritis is of common occurrence. The irritation thus induced greatly lessens the resistance to infection, so that inflammation may extend through the

uterine cavity to the Fallopian tubes, developing tubal disease; consequently the individual suffering from fibroid growths will not infrequently be found to have also obliteration of the tubes and an accumulation of fluid within them. The presence of a growth which has existed for some time and has undergone marked fibrous change is sufficient to irritate the peritoneum and frequently cause ascites. Whether the latter is due to the irritation of the tumor, to the formation of some particular toxin, or to other causes is difficult to determine. The responsibility of the tumor for its occurrence, however, is evident in the fact that, in the great majority of cases, the ascites disappears after its removal. Hematoma of the ovary is so frequently found associated with fibroid tumors as to lead one to feel inclined to attribute to the growth some influence in the production of the condition. This degeneration is more likely to be found where the growth has existed for a long time. Sometimes both ovaries are filled with an accumulation of dark, fluid blood, each ovary forming a thin-walled sac with more or less of adhesions, the attempt to separate which results in the rupture of the sac and the escape of its contents. Where the operator has not been prepared for such an occurrence, the intestines may be extensively soiled. The fluid, however, seems to be innocuous, and very rarely does the patient experience any inconvenience from the rupture.

Another complication of myomata may be the presence of pregnancy. The presence of fibroid tumors is considered to be a cause of sterility, and such patients are not so likely to become pregnant. This is especially true where the tumor is situated within the uterine cavity, is of the submucous variety, either pedunculated or sessile. Pregnancy does occur, however, sufficiently often to be remembered as a possibility or as an explanation for a rapid growth or of some marked idiosyncrasy in its progress. Where pregnancy coexists, it becomes a matter of interest to observe its progress, as we are unable to say in any individual case what influence it will exert upon the growth. Occasionally, under the more active metabolism engendered by the pregnancy, the tumor disappears and is completely absorbed. Such an occurrence has not infrequently led a physician who has seen a patient in whom myoma has been diagnosed, and when careful examination at the time she comes under his later observation fails to disclose any sign of the tumor, to condemn his predecessor as either having misrepresented the condition or having been mistaken in his diagnosis. But the fact that these tumors do disappear should render him cautious and charitable.

The growth more frequently, however, partakes of the accelerated activity of the circulation in the uterus and increases in size. This increase may be so marked as to necessitate operative interference during the course of the pregnancy, in order to save the life of the patient, as the abdominal distention may interfere with the heart's action and with respiration. The presence of a myoma does not exert any special influence on the progress of the pregnancy unless

through the rapid growth just mentioned. Its effect upon the subsequent labor will depend largely upon the situation and number of the growths. If they are situated near the cervix, they may become impacted in the pelvis and so fill it as to render delivery impossible unless preceded by removal of the growth. The enucleation of such a growth as a preliminary to delivery opens up a large amount of connective tissue which has been more or less injured and will be further subjected to trauma, consequently affording soil the most favorable for infection. The presence of growths in the wall of the body of the uterus, although entirely out of the field which will be occupied by the delivery of the fetus, may render uterine contractions ineffective and futile. The dilatation of the cervix consequently is not accomplished, and surgical measures must be resorted to for the delivery of the patient, so that not only is the mother the victim of the double condition, but also the fetus is endangered by the presence of fibroid growths within the uterus.

Course and Prognosis.—As has already been mentioned, small subperitoneal or interstitial fibroids may give rise to no symptoms whatever. They may remain quiescent for a long period of time, gradually increase in size until a tumor is formed which reaches the umbilicus, and yet will not threaten life either directly or indirectly, as would cancer of this organ. A well-marked tumor is often developed, readily recognizable by others, but so insidious in its progress as not to be observed by the patient until some special condition leads her to recognize it herself or it is recognized by a physician who examines the abdomen for some other condition. The submucous and interstitial growths which encroach upon the uterine cavity produce symptoms much earlier. In these the symptoms are those resulting from disturbance in menstruation either in its prolongation and increased flow or irregular bleeding. The hemorrhage may be an indication of nature's effort to separate the growth or the result of interstitial endometritis induced by its irritation. Fibroid growths, as they increase in size and the individual approaches the climacteric, are very prone to undergo degenerative changes, such as have already been mentioned, which make it desirable that some operative procedure should be employed. The interference with the circulation of the pelvis or the formation of toxins which enter the circulation has a deleterious influence upon the heart, inducing cardiac complications. Cardiac lesions are so common as to lead to the supposition that the presence of fibroids is an exciting cause for degenerative processes in that organ.

The symptoms produced by fibroids generally abate at the menopause, but the occurrence of the latter may frequently be delayed for several years; thus, a woman who, under ordinary circumstances would cease to menstruate at forty-five, would continue with a flow unabated ten years later, and the recurring hemorrhages be so serious as to indicate the necessity for some active interference. The operator is often asked as to the necessity of operation for fibroid growths.

When we consider the various degenerative changes to which they are subjected, such as inflammation, suppuration, gangrene, calcification, and malignant disease, either carcinoma or sarcoma, and with these conditions in view analyze a large number of cases, it can safely be said to the patient that she stands less risk through an operative procedure for the removal of the growth than she would if she continues to carry it. A woman suffering from fibroid tumors who becomes pregnant naturally is very anxious as to the probable result. The existence of the fibroid, especially when it occupies the uterine cavity, increases the tendency to abortion. The growth may prove a cause of dystocia or it may undergo changes subsequent to the parturition which may endanger the life of the patient.

Treatment.—The treatment of fibroid growths will depend upon the size of growths, their situation, and the constitutional effects. As these growths increase in size, the uterus necessarily becomes heavy. It is consequently desirable that the intra-abdominal pressure should be diminished and the patient will consequently be advised to wear loose clothing, to keep her bowels well regulated, and to avoid causes productive of uterine engorgement. It has been suggested that the patient may be placed upon a diet which deprives her of the materials which are largely found in the fibroid growth, and in this way make the tissues use up the superfluous material. The treatment is usually divided into medical, electric, and surgical. It was formerly the custom to administer large doses of ergot, continued over a long period, with the view of increasing the activity of the muscular structure of the uterus and thus facilitate the extrusion of the mass, either as a submucous or subperitoneal growth. This method of treatment, however, requires so long a period to produce its effect, led to degenerative changes in other portions of the body as the result of the influence of the drug, that it is no longer advocated. The electric treatment for a time found many enthusiastic advocates, especially after the systematic employment of measured currents, as introduced by Apostoli. The galvanic current was employed, either the positive or negative pole inserted into the uterine cavity, according to the purpose desired. Then the external pole was applied, with a large electrode over the abdomen. Through this measured current from 50 to 100 milliampères were employed, and repeated as the condition of the patient would permit. When the patient suffered from a tendency to bleed and it was desired to control the hemorrhage, the positive pole was employed in the uterine cavity for its electrolytic action. Where the purpose, on the contrary, was to decrease the size of the tumor, the negative pole was inserted within the uterus or thrust directly into the substance of the tumor, in this way producing a marked chemic effect which led to disintegration and absorption of the tumor. It was found, however, that it required repeated treatment to establish changes in the uterine mucosa sufficient to arrest hemorrhage, and that the employment of the negative pole for the purpose of reducing the size of the tumor was not only tedious, but

dangerous. The method of treatment has a place in cases where the patient is unwilling to undergo operation, or when her condition of health is such as to render operative procédure especially perilous.

Surgical Treatment.—The surgical treatment consists in the removal of the growth, through either the vagina or the abdomen. Where the tumur is situated within the uterus, shows a disposition to be extruded, and is otherwise comparatively free from growths, the vagina affords an opportunity for various operative procedures, for either the complete removal of the uterus including the tumor or the preservation of the uterus and the sacrifice of the growth. The tumor may be removed through the vagina by torsion, excision, enucleation or morcellement, and, finally, by hysterectomy. The procedure of election will depend entirely upon the size and situation of the growth. Where the tumor is pedunculated, has been expelled from the uterine cavity, or can be rendered readily accessible through dilating the cervix, it may be very readily removed by torsion. This consists in grasping the tumor with a strong pair of vulsellum forceps. When this is a four-pronged instrument, the tumor can be rotated until its pedicle is completely twisted off, after which it is delivered by traction. Occasionally such a growth in the vagina may be so large as to render its delivery through the vulva, especially in the undilated vagina, exceedingly difficult, and I have in some instances had to divide the tumor, removing a portion of it and thus reducing its size. Another plan for removing such a tumor is by excision of its pedicle. If the tumor is situated in the vagina, it may be of considerable size, rendering difficult the passage of an instrument over it to its neck. The tumor is drawn down as far as possible, the finger as a guide is inserted through the vagina into the uterine canal, then a pair of scissors is introduced with the blades closed until they reach the pedicle of the tumor, when they are separated, and, with the finger already mentioned, acting as a guide, the pedicle can be brought between the blades of the scissors and cut through. This method of procedure was formerly considered to be dangerous, causing peril to the patient from hemorrhage, but it is now recognized that, with gauze packing carried into the uterine canal, any bleeding likely to occur from such a growth can be controlled, so that the application of the écraseur for division of the pedicle of such a growth is no longer resorted to.

The third method of removal of the growth is applicable to those cases which have not been extruded from the cavity of the womb and are attached by a broad base, either sessile or situated within the wall of the uterus. In such cases it may be necessary to split the cervix in order to reach the tumor. The point of the incision will depend on the situation of the growth; thus, within the cavity of the uterus, the incision may be bilateral. If situated in the anterior or posterior wall, the incision should be made through the corresponding lip or in the anterior wall. The incision may be made over the anterior fornix of the vagina, the bladder pushed up and then a transverse incision made at the upper portion of the cervix, and the tumor thus

exposed. An incision may be made transverse, and, if necessary, a second vertical incision may be added. The tissues are pushed back and the growth seized with double tenaculum and separated by blunt dissection, either with the finger or a dissector. In this way the tumor can be enucleated from its bed. The enucleation may thus take place from the anterior wall, the posterior wall, or the cavity of the uterus, according to the situation of the growth. Where the opening is accessible, it may at once be closed. Where it is within the cavity of the uterus, it is well to introduce a wick of gauze for drainage and then to suture the incision in the neck, whether unilateral or bilateral. Morcellement is the removal of the tumor piecemeal, and is applicable to those growths which are too large to be readily brought through the canal. The tumor is exposed either through the cervical canal or by incisions, as already suggested for enucleation. A portion of the growth is then seized with double tenaculum fixation forceps, drawn down, and a section of it cut out. This can best be accomplished with curved scissors or preferably with a double-edged bistoury. Before removing the section, it is well that the remaining portion of the tumor should be fixed with a pair of forceps, so that it can be readily retained in sight. This procedure may go on until the tumor is sufficiently reduced to permit of its ready removal. With the completion of the operation it is wise to follow the course already suggested of the union of the divided surfaces. Provision should be made, however, for drainage by the introduction of a wisp of gauze.

Hysterectomy.—See Vaginal Hysterectomy, p. 540. The abdominal procedures may be denominated as myomectomy, enucleation, supravaginal hysterectomy, and panhysterectomy.

Myomectomy and Enucleation.—The abdominal cavity is opened in the median line; the uterus occupied by the growths is raised. When these growths are situated on the external surface, with more or less marked pedicle, the pedicle may be divided in double flaps and the growth removed, after which the hemorrhage is controlled by a catgut suture, and, finally, the flaps sutured together, covering the stump with peritoneum. A number of fibroid growths may thus be removed from the same uterus, and the organ still be retained in a condition permitting it to perform its proper functions.

Enucleation consists in the removal of growths that are situated within the wall of the uterus, either in the wall or in the uterine cavity. An incision is made over the growth, through which it is seized with fixation forceps, and, as traction is made upon it, the tissues are pushed back with the blunt dissector or with the finger, and the tumor thus completely removed. Where a number of fibroids exist, the aim should be to remove as many of them as possible through one incision, as otherwise, where a number exist, the uterine wall would be pretty well destroyed by the number of incisions. After the enucleation has been made, the openings are closed first by deep sutures, dipping down to but not into the mucous membrane. A number of sutures are introduced to bring the parts into apposition;

then intermediate sutures are inserted, bringing together the superficial edges of the wound and a portion of the wall. After these sutures are tied a continuous catgut suture is introduced, carrying the peritoneum on either side over the line of the wound. In this way a number of growths can be removed and a uterus retained which is capable of gestation.

Supravaginal Hysterectomy and Panhysterectomy.—See Hysterectomy, p. 539.

Carcinoma Uteri.—For carcinoma in general and the pathology of the condition in the uterus see Vol. I.

Carcinoma may affect any portion of the mucosa of the uterus. It is divided, according to its location, into first, carcinoma of the portio vaginalis, *i. e.*, that portion of the cervix situated between the external os and the insertion of the vagina; second, when the disease affects the cervix and is situated between the internal and the external os; and third, carcinoma of the body of the uterus, or that portion of it above the internal os.

Carcinoma occurs in various organs of the body in both sexes, but of the gross number, nearly one-third the cases are uterine. For this reason twice as many women as men die from carcinoma.

Histologically, the disease is divided into the squamous-cell and the cylindric-cell carcinoma. The former is known as epithelioma, and the latter as adenocarcinoma. The most frequent form of the disease is the squamous-cell carcinoma, involving the vaginal portion of the cervix. Next to this is the adenocarcinoma of the cervix. The squamous-cell carcinoma may develop in either the anterior or the posterior lip, or be situated at the site of an old laceration. It begins with small, papilla-like nodules, which are hard at the base and more or less friable on the surface, and bleed on the slightest manipulation. This nodule consists of a proliferation of the epithelial cells, bluish white on the surface. On section, two well-marked zones are distinguished—the first, a peripheral zone of a yellowish gray color, the consistence of brain tissue, which readily breaks down under manipulation; the second, or basal zone, is in juxtaposition with the cervical tissue, is yellowish white in appearance, and of cartilaginous consistency, due to the infiltration of the epithelial cells. These are collected in nests surrounded with fibrous striations of the connective tissue. These collections consist of friable homogeneous tissue, the so-called cancer nests. Pressure upon these surfaces extrudes the collection, presents small shallow depressions which should not be confounded with dilated glands of Naboth. Small papillary projections develop rapidly and form cauliflower-like masses—the condition known as cauliflower cancer. Where this has existed for a length of time, the entire vagina may be filled with a large, rounded mass, grayish white in appearance, the surface covered with slough and exudate, while the entire tissue is exceedingly friable, easily broken down, and bleeds profusely. As the disease advances it progresses toward the vagina, and may involve it and the subjacent

tissue. Infiltration also extends into the structure of the cervix, and in some cases, instead of the proliferation and cauliflower growth, we will find that the surface breaks down, becomes excavated, presents roughened, undermined edges, with a base that is indurated, hard, and covered with friable tissue. Close investigation of neoplasms discloses glistening white trabeculæ of fibrous tissue which constitute the stroma, and thin sections, when compressed and washed out, present a sieve-like structure showing the stroma within the cell collection. There are no symptoms which indicate the development of this early condition, so that the disease is rarely discovered in its early stage.

In the second stage there is a moderate disintegration, breaking down of the surface of the disease, and associated decided symptoms, which usually lead to its recognition. The patient has profuse, irregular bleeding, aggravated by touch and the marital relation. Examination discloses a partial or total destruction of the cervix or an irregular, cauliflower, fungating mass, which bleeds with the slightest touch and is easily broken down, causing the discharge of granular or brain-like tissue. The base of the structure consists of a yellowish white, hard, cartilage-like tissue, and may extend into the vault of the vagina and the connective tissue of the broad ligaments.

The third stage is characterized by extensive or complete destruction of the cervix extending to the circumjacent structures. This form is recognized from the history alone, and without a vaginal examination. The entire cervix is destroyed, and the disease extends upward into the cavity of the organ, often presenting a sloughing, crater-like cavity, and, when the diseased tissue is scraped out, it leaves the womb a mere shell. Before this, however, it has invaded the structures upon either side, so that the parametrial tissues are extensively involved and the uterus well fixed. When it extends forward, involving the anterior wall of the vagina, the bladder may also become involved, and when this breaks down, it leads to the formation of a fistula. Not infrequently the ureter is involved or surrounded by a mass of infiltrate which compresses it and interferes with the passage of the urine into the bladder. Fistulous communications are often found between the bladder and the vagina or the rectum and the vagina.

Adenocarcinoma of the cervix has its origin in cylindric cells covering its mucous membrane. It may begin either in the superficial cells or in those lining the glands of the canal. It probably has a combined origin from both the glandular and surface epithelia. It may begin as a rounded nodule, and involve almost the entire cervix before disintegration follows, or it may develop in the form of tubercles, nodules, or papillary growths within the lumen of the cervical canal, which fill up its cavity or extrude from the os, while the external surface of the cervix is slightly involved. Occasionally the entire cervical canal is involved without any pathologic changes being

perceptible about the external os. It appears as a hard, firm, waxy mass. In other cases the disease is associated with extensive inflammation of the diseased mucous membrane, as well as the muscle and cervical wall, which causes thickening and hardening of the entire cervix. As the disease advances nodules undergo necrosis, leaving a sloughing, crater-like cavity in place of the canal. When the disease is confined to the upper part of the canal, it may remain for a considerable time wholly unsuspected. As it progresses, it gradually extends downward and breaks through the external os, but more frequently, unless laceration of the cervix has previously existed, it breaks through the cervical wall into the parametrium before the change is manifest outside the external os. The cervix above the internal os may be extensively disintegrated before the disease breaks through the latter. The ulceration rapidly penetrates the cervical wall, invades the parametrial connective tissue, and this may take place without any break in the continuity or any disturbance of the squamous epithelium of the portio vaginalis. Observation of the destructive influence of glandular infection of the cervix affords an explanation for the rapid invasion and penetration of the cervical wall, as we not infrequently find the entire cervix involved in cystic degeneration of the cervical glands. Occasionally the uterine mucous membrane may be the seat of isolated cancer nests, the result of metastasis. The disease may penetrate the peritoneum, but the vesicocervical septum is more frequently invaded. The ureter is probably involved in this form of disease more often than the bladder.

Adenocarcinoma of the Body of the Uterus.—Adenocarcinoma of the body of the uterus has its origin in the mucous membrane lining the cavity, and arises either from its epithelium or from that lining the tubular glands. It occurs later in life, and is more likely to develop in women who have not given birth to children. It consequently affords the most hopeful outlook of any of the different varieties of uterine cancer. It may have its origin at any point in the cavity above the internal os. It is unusual for the disease to extend toward the internal os, and it rarely reaches the external os. It may begin as a circumscribed nodule, springing from the surface of the mucous membrane, and consists of several delicate, papilla-like processes. These processes may be irregular in their outline, or the surface of the growth may appear perfectly smooth. The nodule gradually increases in size and extends about its base, so that several smaller nodules will frequently be found. I have seen it appear like a simply polypus, beginning in a few glands, and project from the mucous membrane like a cauliflower growth of the cervix, the proliferation increasing until the entire cavity is filled, and yet it may have only a small point of attachment to the surface. Such a growth may resemble the benign mucous polypus, but is more fragile; its surface is less smooth, and it is more prone to hemorrhage. The proliferated mass also is much larger in comparison to the size of its pedicle than is found in any benign growth. The disease of the body

is generally a localized growth, though occasionally it may apparently simultaneously involve the entire mucous membrane. The projections or outshoots grow toward the direction of least resistance, and consequently fill up the entire uterine cavity. Such a uterus will be somewhat enlarged, feel more or less boggy, with possibly points of infiltration and hardness. The disorder may be suspected from the increased hemorrhage and offensive discharge. The diagnosis is made sure by dilatation of the cervix and the introduction of the finger, which reveals the cavity filled with a soft, friable, grayish yellow material, with a more or less hardened, infiltrated base.

The tendency of the disease is to invade the deeper structures and gradually penetrate the wall of the uterus. Carcinoma is not confined to the organ in which it develops, but manifests a disposition to spread not only to contiguous tissues, but by the lymphatics, to structures more or less remote, where it forms foci or nests of a character similar to the original. The principal method of introduction is through the lymph-channels. The epithelial cones project into the connective-tissue folds until they reach the large lymph-spaces. The disease is then carried to the lymphatic glands, which act as guards and for a time arrest its further progress. Unfortunately, however, it is not long before these barriers are overcome, when the disease reaches the deeper glands, involving those upon both sides of the aorta in the lumbar region. The early invasion of those glands makes the successful excision of the glands impossible. The disease is more rapid in its progress when it is associated with pregnancy, or in women prior to the climacteric. The younger the woman and the more active her lymphatic circulation, the more rapid will be the metastasis, and the less hopeful the prognosis. When the disease occurs late in life, after the uterus has become atrophied and its lymphatics greatly diminished, the invasion is much slower and the disease is more likely to be confined for a length of time to the point where it originates. The proliferation and infiltration of the structures lead to obstruction of the circulation, which soon causes the new tissue to break down with ulceration and loss of structure. Around the ulcer is a zone of infiltration, and around the latter the demonstration of nature's attempt to limit the disease by round-cell infiltration or an inflammatory zone. The disease is more likely to occur at or near the climacteric, although, it may develop at any period of the active sexual life of the individual. I have seen it as early as twenty years of age.

Symptoms.—The symptoms which are usually attributed to carcinoma are pain, hemorrhage, and offensive discharge. Unfortunately, these are not pathognomonic and may occur late. There is nothing in the early stage of the disease which would be likely to indicate its presence, either to the patient or the physician, and when the symptoms mentioned occur, it may be too late to afford any radical relief. Of these symptoms, bleeding is the most important. It may be very slight, *e. g.*, a few drops after straining at stool, after making any exertion, or following coition. As the disease advances, post-coitive

hemorrhage is a very constant symptom. In view of the possibilities hemorrhage, or even bleeding, should always be considered as a danger-signal demanding the most careful investigation to determine its cause. This is especially to be appreciated when the bleeding occurs subsequent to the climacteric. After the cessation of menstruation the patient may have an occasional slight discharge of blood, which she may think is a return of the menstrual flow. It cannot be too strongly impressed upon women that bleeding at this period of life, even though slight in character, is a peremptory indication for a careful investigation. As the disease advances the hemorrhage increases. It may be very profuse, a bright stream, or occur in clots.

In association with the hemorrhage, sometimes preceding it, the patient will have a very profuse watery discharge, of a stale, sweetish odor. Later, this discharge is mixed with traces of blood, is yellowish in color, may contain fragments of tissue, and become reddish brown or, finally, a dark, smeary mass. This is due to the ulceration and disintegration of the affected structures. The odor becomes more disagreeable, and, finally, has a penetrating, stinking smell, exceedingly distressing to the patient and to all who are obliged to attend her. Such patients are frequently accustomed to having a discharge, and this is not noted or complained of until the odor becomes so offensive as to be no longer endurable. The odor is due to the presence of putrid or saprophytic germs. The loss of blood, the offensive discharge, the absorption of decomposing products, lead to marked progressive anemia and to a cachexia. Contrary to the usual belief of patients pain is a late symptom. The cervix is not a very sensitive structure, and consequently it may become extensively diseased and broken down without producing any pain. Pain is usually a symptom of the invasion of the paracervical tissue. It increases as the disease extends upward, involving the endometrium, the contiguous tissue to the bladder, the rectum, or presses on the ureter.

Physical signs necessarily depend upon the part of the uterus which is involved. Thus, in the portio vaginalis either a cauliflower-like mass fills up the vagina, which is found to be continuous with the cervix, exceedingly friable to the touch, and bleeding easily, or the cervix is destroyed and presents an excavated cavity, with more or less hard, dense, infiltrated edges. When the disease exists in the cervix, in the form known as adenocarcinoma of the cervix, no external ulceration and no visible sign of disease may be perceived. Examination by touch, however, reveals the cervix to be dense, or that it presents points of hardness. Pressure upon the cervix may cause an offensive discharge or bleeding from the external os. The cervix is generally somewhat enlarged. In carcinoma of the body of the uterus the cervix may be free from any disease, the body may be slightly enlarged, present a soft mass, portions of which may be extruded into the vagina as the result of pressure and manipulation, or the wall of the uterus may present points of distinct hardness due to infiltration of the base. In the very early stages of the epithelioma it presents small nodules

or elevated masses, with a cartilage-like feel at the base, which might readily be mistaken for obstructed glands of Naboth. In the follicles of the latter, however, the surface presents a smooth outline, and is either whitish or yellowish, according to its contents. Puncture of the projection allows a thick, viscid material to be discharged, with collapse of the cyst, while puncture of a tubercle arising from malignant disease is attended only with discharge from its surface, while the base is hard and firm.

Carcinoma of the uterus may be complicated by ovarian tumor, myomata, peri-uterine inflammation, and pregnancy. Ovarian tumor may be either malignant or benign, but does not necessarily have any causative relation to the production of carcinoma, but when we realize the frequency of carcinoma of the uterus, and that fibromata occur in at least one-third of all women over thirty years of age, it does not seem surprising that the two diseases should occur simultaneously. Peri-uterine inflammation is not infrequent; in fact, as the disease advances, nature endeavors to establish limits to its progress and consequently forms an inflammatory barrier, the extent of which will depend somewhat upon the tissues involved. When it occurs in the peri-uterine tissues, the existence of such inflammation, however, need not necessarily be considered as a consequence of malignant disease, as it may have preceded it and be due to other forms of infection.

Pregnancy is not a very frequent complication. In the majority of cases carcinoma occurs late in life, at a period when pregnancy is unlikely. In addition, the disease itself tends to the development of sterility. Where pregnancy does occur, the gravity of the prognosis of the disease is increased.

Diagnosis.—It is rare that carcinoma is diagnosed in its early stages, because there is nothing to lead to the suspicion of its development. Women who are suffering from lowered vitality and constitutional conditions which render them less resistant to the occurrence of such a disease would do well occasionally to be examined to make sure that the pelvic organs are in a healthy state. Lacerations of the pelvic floor, displacements of the uterus, recognized inflammatory changes, should be corrected with a view to prevent the development of malignant conditions.

It has been shown how the glands of Naboth may be distinguished from malignant nodules. In the more advanced stages of the disease the proliferation and cauliflower-like growths, upon the one hand, and the ulceration, destruction of tissue, and the infiltrated hard base, on the other, are sufficient to render certain the diagnosis of carcinoma in the cervix. In the cervical canal and that of the body of the uterus the offensive discharge, the bleeding, sensation of hardness and resistance, points of increased resistance in the wall of the uterus should be sufficient to justify the strong suspicion of the presence of the disease. The diagnosis may be rendered certain by dilatation of the uterus and the exploration of its cavity by the finger, by the

removal of tissue obtained either by means of the curette or by sections, where the cervix is involved, and the examination of such tissue under the microscope. The microscope reveals the stroma or trabecular arrangement of the tissues, with accumulation of cells in the spaces known as the cell-nests. This arrangement of the structure will be sufficient, and shows also its tendency to break down and to extend to the surrounding structures. It is desirable, in removing tissue for examination, that the section should involve both the diseased and the adjoining healthy tissue, so that the transition from the one to the other may be recognized.

The conditions with which carcinoma may be confounded and from which it must be differentiated are chronic cervical catarrh with laceration, papillary erosion of the cervix, necrosis or fibroid polypus, syphilitic ulceration, partial retention of the products of conception, chorio-epithelioma, and sarcoma.

In *chronic cervical catarrh* and laceration the more delicate epithelium of the cervix is exposed, inflammatory changes take place, the ducts of the glands become narrowed and closed, secretion accumulates within the glands, eversion of the mucous membrane follows, and there is a thick, viscid discharge. In these cases, while the parts are thickened and somewhat indurated, it does not present the hard, dense base that is associated with malignant disease nor is the surface of the tissue friable and easily broken down, although bleeding may take place freely where there is extensive granulation. The absence of loss of tissue is generally sufficient to confirm the diagnosis. Where there is any doubt, a section of the tissue should be subjected to microscopic examination.

In *papillary erosions of the cervix* the papillæ are exposed, become enlarged, present a red, angry appearance, and the surface looks as if it were raw. Investigation under the microscope, however, shows that the surface is covered with the cylindric epithelium, possibly in a single layer, and there is absence of any infiltration or peculiar aggregation of cell structure, as in the malignant disease. Necrosis of fibroid polypus may be simply superficial, or involve its entire structure. This may cause hemorrhage, an exceedingly offensive discharge, and lead to progressive anemia. The digital examination of the mass, however, is sufficient to show that the structure is hard, dense, firm, smooth in outline, and that only its superficial surface is undergoing ulceration or desquamation. In other cases where the entire structure is involved and the tumor may be breaking down, fragments of it may be pulled off which show the peculiar arrangement of the fibrous structure of the growth, and even its macroscopic appearance is sufficient to afford a positive diagnosis.

In *syphilitic ulceration* there is loss of tissue and ulceration of the cervix, but it is covered with granulation tissue and rarely has an infiltrated or firm base.

In *partial retention of the products of conception* hemorrhage and offensive discharge will be present, and cause fear of some malignant

condition, but the history of the case, examination of the patient, and digital examination of the uterine cavity are sufficient to disclose its true character, and upon removal of the material the symptoms cease.

Chorio-epithelioma follows an abortion or recent labor. The tissue removed by the curette very much resembles placental tissue. It has not the structure of carcinoma, there being the absence of stroma.

Sarcoma may occur at the same period of life as carcinoma, and may involve either the cervix or the body, but the uterus is likely to increase in size to a greater degree, with less breaking down of its structure. Hemorrhage is possibly more profuse, and under microscopic investigation the section shows the connective-tissue cell without stroma.

Prognosis and Duration.—Unfortunately, we do not know enough of the origin of cancer, the methods by which it is carried from the point of original development, and the varying resistance of the individual to determine in any special case an absolute prognosis. Cases are seen in which the uterus is perfectly movable, in which the disease seems to be confined to a small portion, where the probability of excision through the healthy tissue is excellent—cases in which we would feel that the outlook should be favorable, and yet the removal of the disease is followed by early recurrence. There are other cases in which the cervix is extensively destroyed, in which it would seem that operation would be exceedingly difficult, and yet operation has been followed by years of absolute freedom from any return. It is customary to regard cases as cured only after five years without recurrence. Why it is that the cancer-cells or the cause for the production of the disease can remain in the tissues of the individual from three to five years before reproducing its kind is a difficult question to solve.

It is very difficult to fix a duration for the disease when we are unable definitely to determine its early stage. The progress of the disease will also depend upon the period of life at which it originates. Thus, the earlier it occurs, the more rapid its progress. If it occurs late in life, after the lymphatics have undergone the atrophy which follows the climacteric, the disease is much slower in its progress. From one to three years would probably cover the duration of the disease in the majority of cases when undisturbed.

Treatment.—The treatment of carcinoma may be divided into the palliative and radical. The former should be considered only in those cases in which the disease comes under observation so late that it is no longer possible to accomplish its entire removal, *e. g.*, when the disease has passed from the uterus into the parametrial tissues, or when it has passed through the lymphatic tissues to the lymphatic glands. In such cases the treatment will depend very much upon how far advanced the disease is. When the patient is suffering from profuse bleeding, foul discharge, the absorption of toxic products, and subsequently develops a marked cachexia, even though we are unable

to extirpate the entire disease, we can very greatly improve her condition for the time being by thoroughly curetting and scraping away the diseased tissue, cutting off the ragged edges, and, after arresting the hemorrhage, thoroughly cauterizing the surface with the thermocautery. The bleeding can be controlled by infiltrating the tissues with one part adrenalin chlorid to three parts salt solution. The control of the bleeding in this way enables the operator to see the field which is to be cauterized and to apply the cautery more effectually. By having a dry field, more tissue is destroyed, and consequently the zone which is liable to break down is thus cleared, with the discharge of the slough. After the surfaces have been thoroughly cauterized the cavity may be packed with iodoform gauze, or preferably with gauze wrung out of a 2 per cent. solution of carbolic acid. Carbolized gauze acts as an anesthetic to the burnt surface. The gauze should be permitted to remain about three days, when it is removed, and the cavity then irrigated with normal salt solution. After the removal of the slough, the progress of the disease can be made much slower by swabbing the surface with tincture of iodin two or three times a week, and afterward packing it with iodoform gauze. The arrested hemorrhage, the removal of the disintegrated tissue, and the decreased discharge result in temporary marked improvement. Where the parametrial tissues are extensively involved, the only treatment is to keep the patient clean and ease her pain. She should be in a well-ventilated room, and douches of permanganate of potash alone, or alternating with thymol solutions, should be employed.

For radical treatment see Hysterectomy (p. 539).

Sarcoma.—Sarcoma may occur in either the mucous membrane or the wall of the uterus. Like carcinoma, it may develop in either the body or the cervix—more frequently in the latter. It occurs with much less frequency than carcinoma. It has its origin in the connective tissue. In the cervix it develops in the mucous membrane as small nodules or polypoid projections which may hang from the external os. These grape-like clusters are easily broken and bleed freely. It is advisable, in every case of mucous polypus projecting from the surface, that its structure, and particularly that of its base, should be examined to make sure that it is not sarcomatous. When the disease develops in the uterine wall, it may begin as a sarcomatous growth or have its origin in a degenerating fibroid. The latter is gradually infiltrated by sarcomatous degenerated tissue.

The *symptoms* of sarcoma of the uterus are similar to those of carcinoma—hemorrhage, foul discharge, and pain, the latter less marked than it is in carcinoma. In sarcoma the uterus increases in size, and it is more soft and less resisting. The tissue presents a homogeneous appearance, absence of stroma, not infrequently the vessel-walls having been destroyed. The increasing size, the absence of induration and of any stroma on microscopic examination, serve to render the diagnosis certain.

Treatment.—The treatment, as in carcinoma, may be either palli-

ative or radical. Palliative treatment consists in systematic measures to make the patient more comfortable.

For radical treatment see Hysterectomy (*vide infra*).

Chorio-epithelioma.—Malignant disease of the uterus originating in embryonic tissue is a condition which is now known as chorio-epithelioma. It was formerly supposed to be a degenerative change in the mole, but later investigation has shown that the presence of a mole is unnecessary. The disease has its origin in the syncytial cells. (For histology and pathology, see Vol. I, p. 813.) The disease follows an abortion, permature labor, or labor at term. After a few days to a few months repeated bleeding occurs, which gradually increases, and the patient suffers from prolonged hemorrhage. She will necessarily become quite anemic, extremely weak, and develop a cachexia. Examination of such a uterus with the curette results in the removal of a large quantity of friable tissue resembling the placenta, and associated with free bleeding. The uterine cavity is filled with necrotic tissue, which bleeds profusely, and from which the discharge is exceedingly offensive. The disease not infrequently presents metastases in the anterior wall of the vagina in the form of small nodules, which, when incised, show tissue similar to that removed from the uterus. The curettage of the uterus affords relief from hemorrhage but for a brief period, and subsequent curettement displays a reformation of the tissue. Unlike carcinoma, the disease is carried through the blood-vessels, producing metastasis in organs quite remote from the site in which it originated, *e. g.*, in the liver, spleen, kidneys, intestines, diaphragm, pericardium, lungs, and pleura.

Diagnosis.—When a patient gives a history of pregnancy terminated either at term or during gestation, which is followed by profuse bleeding and foul discharge, and the formation of placenta-like material, the suspicion of a malignant condition is justifiable. The examination of the curetted tissue discloses multiplication of the large decidual cells. Where there is a rapid return of hemorrhage after curettement, with profound anemia, elevated temperature, enlarged uterus, dilated os, and soft, friable tumor, but little room is left for doubt, and its grave character is further confirmed by the development of metastases which most frequently are found in the vicinity of the original trouble—in the vagina. The existence of a mass which discloses material of a homogeneous character without stroma makes it akin to sarcoma. It is distinguished from this disease, however, by its epithelial elements. The *prognosis* is most grave. The *treatment* must be radical, and one which will insure the entire removal of the disease. The fact that the disease develops rapidly and metastases are liable to occur renders it evident that it should be recognized and treated early.

Hysterectomy.—Hysterectomy means the removal of the uterus, either partial or complete, and may be performed either through the vagina or by an abdominal incision. Hysterectomy is done for diseased conditions within the uterus, such as fibroid growths, malignant degeneration, and inflammatory conditions which are sufficient

to necessitate the sacrifice of the ovaries and tubes, and where the uterus has undergone more or less change as the result of infection. The vaginal operation is attended with very much less discomfort to the patient, with a shorter convalescence, and with less danger of hernia. It requires, however, that the vagina should be dilated or readily dilatable, that the uterus be not too large for its ready removal through this canal, and that the organ should be movable and easily brought down. Where the uterus is fixed high in the pelvis with a certain amount of inflammatory exudate, and the vagina is long and narrow, the vaginal operation will be attended with the greatest difficulty and increase the danger to the patient.

Vaginal Hysterectomy.—*Preparation.*—The patient prepared for hysterectomy should have had the alimentary canal thoroughly cleared out. The urine should be carefully examined, as well as the condition of the heart and lungs. During the twenty-four hours preceding the operation her diet should be restricted to food that will produce very little waste. A free enema to wash out the lower intestine should be given the morning preceding the operation. She should also be given a hot bath twenty-four hours prior to operation, and be kept in bed afterward. On the night before the time set for the operation the abdomen, as well as the external genitalia, should be thoroughly scrubbed with soap and hot water. While it is customary to apply a dressing over the abdomen during the night, I do not think this is wise, as it keeps the patient's attention fastened upon the possibilities of the operation and tends to prevent her from resting. It is better that the abdomen should be again thoroughly washed the next morning, and then covered either with an aseptic or antiseptic dressing until the time for the operative procedure. After she is placed under an anesthetic, the vagina is thoroughly scrubbed with a piece of gauze and tincture of green soap and hot water, scrubbing the entire surface of the vagina in order to remove all deposits within its crypts and folds. The soap is removed by sterile water, and finally the vagina is washed with alcohol. When the cervix is the site of malignant disease, it may be desirable to scrape away ulcerating, broken-down tissue, cut off projecting fragments, and, where it is possible, suture the healthy tissue over the diseased, or this may be covered up by the use of a number of pair of double tenacula, which are hooked in each lip and thus close the opening. In malignant disease the broken-down surface is loaded with bacteria, which of themselves are productive of infection of the tissues opened up, but the greater danger is the implantation of fragments of the malignant disease upon the surface, causing its subsequent recurrence.

Instruments.—The operator should be provided with four double tenacula, two fixation forceps, four retractors, two long tissue forceps, scissors, curved and straight, a dozen hemostats, two pedicle forceps, a myoma screw, needle-holder, ligature carrier, and assorted needles, short and long curved, these threaded with silk-thread carriers.

Operation.—The method of operation will depend upon the con-

dition for which it is performed. In carcinoma of the cervix the raw surface should be covered over, as has been suggested, by suture, or the healthy surfaces pinned together by double tenacula over the diseased tissue. Even in fibroid growths it is well to seize the cervix with two double tenacula, applied in such a way as to close the opening and prevent the discharges from the uterine cavity entering the vagina.

An incision is carried around the cervix below the bladder and through the vaginal wall posteriorly. Through this incision the bladder is pushed away from the cervix in front until the peritoneum is reached. Similarly the tissues are pushed away from the cervix until the peritoneum is reached and opened posteriorly. Into the opening a long gauze pad is carried so as to hold back the intestines. The lower part of the broad ligament on either side may now be clamped or ligated, and while the ligature is held tense and the cervix pulled in the opposite direction, the tissues are cut through between the ligatures and the cervix. The ligature is cut short to prevent its being drawn off the stump. The peritoneum is opened in front, and the fundus of the uterus drawn down through the anterior fornix. One or two fingers passed over the fundus reach the broad ligament, pulling down the ovary and tube; ligatures are inserted and tied, after which the broad ligament is clamped above the ligature with a strong hemostat. The broad ligament is cut through between the ligature and the uterus. A similar course is pursued upon the opposite side, and the uterus entirely removed. After the removal of the uterus, if any vessels bleed, they are seized with pressure forceps and ligated.

Complete hemostasis must be obtained. When this has been accomplished, the peritoneal surfaces are united to the vagina front and back. Each stump is drawn well down into the vagina, and a suture introduced at either angle, through the anterior wall of the vagina, through the stump, and out through the posterior wall of the vagina, and this suture tied over the stump, so that it is subsequently held in the angle of the vagina. A purse-string suture is finally inserted, beginning in the anterior peritoneum through the stump on one side, the posterior peritoneum, the stump of the opposite side, and brought out on the anterior fold in the peritoneum. This suture, thus inserted, after the inspection of the cavity, making sure that all instruments and gauze pads are removed, and that no portion of the omentum or intestine drops down to be pinched, is drawn tight and tied. This procedure closes the peritoneal cavity. The stumps in the vagina may now be pushed back behind the vaginal wall, and the latter closed by continuous catgut suture. The operation thus performed shuts out from the peritoneai cavity all raw surfaces. If any bleeding occurs, it will take place into the vagina. In the performance of this operation enucleation of the growths may be necessary at times in order to reduce the size of the uterus and to permit its being brought more readily through the anterior fornix. When the growths are of considerable size, however, it is wiser not to undertake the vaginal

operation. In carcinoma, where the disease has taken up the greater part of the cervix, either in the squamous- or in the cylindric-cell variety, it is wiser to do abdominal hysterectomy, as the latter permits a wider removal of tissue and less danger of injuring important structures.

Abdominal Hysterectomy.—Abdominal hysterectomy may be partial or complete. Partial hysterectomy is supravaginal, or the removal of the fundus of the uterus, performing the amputation at the junction of the neck with the body, or between the internal and external os. This operation is the one which is most frequently performed, and is employed in the treatment of fibroid growths of the uterus. It is contraindicated where there has been any marked injury to the cervix, or where a condition exists which would render possible the occurrence of malignant change, or where any part of the uterus is already the site of malignant degeneration.

Instruments.—See Vaginal Hysterectomy.

Partial or Subtotal Hysterectomy.—As in vaginal hysterectomy, the vagina is thoroughly cleansed, an incision is made through the abdominal wall in the median line, beginning just above the symphysis and extending upward to the umbilicus, or above it, as may be necessary for the delivery of the growth. Having opened the abdominal cavity, the relations of the tumor are investigated, and the mass, penetrated by a myoma screw, is raised up and drawn out of the abdomen (Fig. 173). The broad ligaments, including the round ligament external to the ovary and tube or internal to one ovary, if its retention is desired, are clamped with strong forceps, and an incision made through the ligament on either side, between the clamp and the uterus. An incision is carried across the peritoneum in front of the uterus, connecting the two lateral incisions, and the peritoneum and bladder are pushed down. As the broad ligament is thus spread out the uterine artery can usually be recognized and should be clamped. The cervix is then cut across, and the uterine artery of the opposite side secured, after which the mass is removed. The clamped ovarian and uterine arteries are now ligated, the forceps removed from the uterine arteries, and the cavity sponged out to make sure that bleeding is controlled. The broad ligaments are then placed in the sulcus and the suture introduced in the tissue of one side, carried underneath the ligament, and in the tissue of the flap of the opposite side. This suture ligature is then tied external to the forceps on the stump, and a few stitches taken in the stump, so that it shall not slip. Each ligament stump being thus secured in contact with the remainder of the cervix, the parts are thoroughly cleansed, and the intervening raw surface united by continuous suture. Having in this way closed off the stump from the peritoneal cavity, the parts are carefully investigated to make sure that hemorrhage is controlled, that from slipping of a ligature no artery is spurting, and, after the removal of all gauze pads, the abdominal wound is closed. In closing this wound it is my custom to begin at the upper angle of the wound with a needle

armed with a suture of chromic catgut, which is introduced through the aponeurosis, muscular structure, and peritoneum of the right side, and the external end of this suture secured with the hemostatic forceps. The needle is then brought out through the peritoneum only of the left side, and continued through the remaining length of the wound, uniting the peritoneal surfaces until the lower angle of the wound is reached, when it is brought out through the muscular wall and the aponeurosis of the left side. The surface is then dried with gauze and interrupted silkworm-gut sutures, introduced about 1 cm.

Fig. 173.—Subtotal Hysterectomy. (Montgomery.)

apart, inserted and emerging the same distance from the edges of the wound, and carried through all the tissues down to the peritoneum. After the sutures have been placed, the catgut suture is again resumed, and unites the edges of the aponeurosis until the upper angle of the wound is reached, when the end of the suture that had been left clamped with the hemostat is now utilized in tying the only buried knot. The silkworm-gut sutures are tied, drawing them only tight enough to hold the surfaces well in apposition, and between each of these sutures a superficial catgut suture is inserted.

Panhysterectomy.—Panhysterectomy means the removal of the

entire uterus, ovaries, and tubes. The ovary may or may not also be removed. The tumor is exposed, as in the previous operation, the myoma screw inserted, and the mass drawn well over the symphysis, while the intestines are walled back with a long strip of sterile gauze. An incision is then made beneath the cervix into the posterior fornix of the vagina. This is most readily accomplished by having previously introduced a bougie or a pair of forceps into the vagina, which an assistant pushes up, thus disclosing the site of the posterior vaginal fornix. Through the vaginal incision the cervix is seized with fixation forceps and is drawn into the opening. An incision is

FIG. 174.—TOTAL HYSTERECTOMY, DOYEN METHOD. (Montgomery.)

then made around the vagina, separating it from the cervix (Fig. 174). This incision being completed, the cervix is pulled upon and separated from the bladder by blunt dissection. As we proceed and the tissues are torn, the uterine arteries can be seen either before they tear or immediately afterward, and each be clamped with a hemostat (Fig. 175). The traction on the cervix is continued until the peritoneum above the bladder is reached, when this is pushed back and the remaining portion of the broad ligament on either side clamped and cut external to the ovary and tube. This procedure is known as the Doyen operation. The uterine and ovarian arteries are now ligated with chromic catgut, the peritoneal surfaces united over the vagina

with a continuous suture of the same material, turning all stumps into the vagina. Having completed this closure and inspected the surface to make certain no bleeding exists, the gauze pads are removed and the abdominal wound is closed, as in the method previously suggested. Unfortunately, not every case can be thus easily managed. The fibroid growths may involve the uterus to such a degree as not to permit it to be lifted, or they may be complicated by extensive inflammatory adhesions and short ligaments, so that the uterus is prevented from being raised, and the operator cannot reach the posterior vaginal fornix. In such cases the procedure, which has been previously suggested, of clamping and cutting the broad ligaments on either side, can be practised until the uterus is thus permitted to be

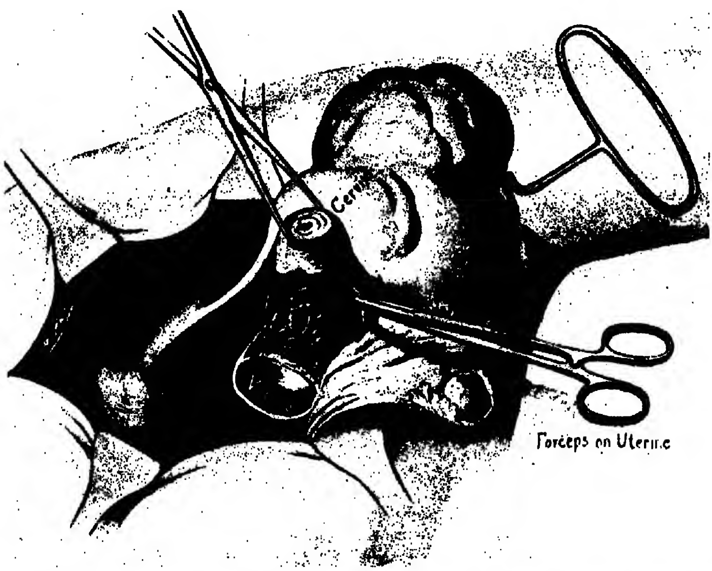


FIG. 175.—CERVIX SEPARATED FROM THE VAGINA AND BEING PULLED AWAY FROM THE BLADDER AND URETERS. (Montgomery.)

raised up, and the vagina opened into, separated from the cervix, and the mass removed. But neither is the latter method applicable to all cases, because we may find that the broad ligaments are occupied by intraligamentary fibroids, so that we can neither reach the posterior fornix nor go down upon either side of the uterus. In some cases the uterus can be reached from above, the uterus thrown back into the abdomen or dragged upward, and the bladder pushed down, the vagina opened in front, the cervix seized, drawn forward, and separated from the vagina. In this case the uterine arteries are first ligated. Where this procedure cannot be employed, it is well to split through the tumor and uterus, dividing the latter into two portions, removing first one-half and then the other (Fig. 176). In this way intraligamentary fibroid growths which fill up the broad ligament on either side are easily

shelled out of the peritoneal folds, separated from the ureters, and injury to these ducts avoided, which would not be possible had the attempt been made to operate upon the broad ligaments from above. In hysterectomy for carcinoma of the uterus it is desirable that as much of the parametrial tissue should be removed as possible. In order to do this the broad ligament is raised on the one side, clamped externally to the ovary and tube, the round ligament is clamped well out on the side of the pelvis, and this portion of the broad ligament cut through. The opposite side is treated in the same way. The

FIG. 176.—SPLITTING THE TUMOR AND THE UTERUS AND REMOVAL OF EACH HALF.

peritoneum above the bladder is then cut through, and the bladder and peritoneum pushed downward. The tissues of the broad ligament are spread out, the ureter looked for, and a pair of forceps or the finger pushed through in the line of the ureter, and the tissue above it, which includes the uterine artery, is clamped or ligated and cut. The uterosacral ligaments are cut posteriorly. This permits the uterus to be well drawn up, and the operator to get below the cervix upon the vagina. With a pair of angular forceps the vagina is clamped on either side below the cervix, and cut through below the forceps. In this way any discharges from the uterus and infectious tissue from

a cervix are retained and removed with the mass. The vagina below is carefully sponged out, all bleeding vessels secured, the uterine arteries on either side having been previously ligated; the ovarian arteries and the ends of the round ligaments are each separately ligated. In this way the parametrial tissue and the glands which are likely to be the seat of infection are readily removed. Enlarged glands in the inguinal region upon either side are then removed, as well as those at the bifurcation of the aorta posteriorly. As far as possible the peritoneal surfaces are united. The cavity of the pelvis may be packed with iodoform gauze, the end of which is brought out into the vagina. The abdominal wound is closed in the methods already suggested.

After-treatment.—The convalescence of the patient after a vaginal hysterectomy is much more rapid and attended with less discomfort when the conditions are equally grave than where the diseased structure has been removed through an abdominal incision. The only dressing in these cases consists in packing some iodoform gauze into the vagina, which packing may remain for three days, except in those cases in which the peritoneum was not closed above the vagina, and the gauze has been packed directly into the peritoneal cavity holding up the intestines. In such cases the gauze should be left for five or six days. During this time adhesions are formed which prevent the intestines being dragged down with the removal of the gauze; also the gauze has become saturated with serum and plastic material from the abdominal cavity, and is easily drawn away from the viscera. If it is removed at an earlier date, a knuckle of intestine is sometimes so firmly adherent to the surface of the gauze that it is drawn into the vagina, causes worry, and, if not recognized, might very readily produce unfortunate adhesions. I have seen a number of cases of vaginal hysterectomy in which a coil of intestine had become adherent to the surface sometimes producing obstruction during the convalescence, and at other times being the cause of fatal obstruction years after the original procedure. Even though such an adhesion does not interfere with the caliber, it may cause obstruction under peristaltic action; the adhesion is a fixed point, the bowel becomes twisted, its caliber obstructed, and the patient suffers and probably perishes, with all the symptoms of strangulation. I have known instances in which the patient suffered from symptoms of obstruction so profound as to lead to fecal vomiting. When later it became untwisted there would be a copious movement of the bowels, and the patient would consider herself recovered. But it is unsafe to leave such a patient without reopening the wound and separating the adhesions.

In abdominal hysterectomy a patient much enfeebled by loss of blood and a prolonged operation may suffer profoundly from shock. This is best treated by keeping her perfectly quiet, surrounded with hot bottles, warm blankets to maintain the body heat, the application of bandages to the extremities, each leg being bandaged as far as the trunk; the arms may also be bandaged, thus throwing the blood back

into the more vital centers, where it is most needed; the administration of remedies with a view to stimulate the heart's action, and also to keep the blood-vessels contracted. For the latter purpose possibly some aseptic preparation of ergot is most effective. It promotes the contraction of the blood-vessels and acts consequently through the whole circulation. Strychnin, digitalis, adrenalin chlorid, and ether are the most active agents which may be administered hypodermically. Salt solution may be injected into the bowel, giving three or four ounces every three hours, by hypodermoclysis, the needle being inserted beneath each breast, and one pint of salt solution thus introduced in each side, or, when the shock is profound, the administration of salt solution by intravenous injection, through opening of a vein in the front of the arm and the insertion of a cannula or needle, through which the salt solution is introduced. One or two pints of salt solution may thus be employed. Too large a quantity should not be employed, as the heart may become flooded and it may be dammed back in the lungs, causing pulmonary edema. Where the patient has lost considerable blood and still shows a disposition to bleed, 1:1000 solution adrenalin chlorid, 1 to 2 drams, or caffein citrate, 3 to 5 grains, may be added. If she perspires freely, the skin showing a disposition to leak, atropin sulphate, $\frac{1}{100}$ to $\frac{1}{120}$ grain hypodermically, should be given. Direct transfusion of blood, as done by Crile and others, may be of the greatest service, and save life, even in desperate cases (p. 615).

One of the most frequently distressing symptoms after operation is vomiting. This takes place as a result of the anesthetic, but such vomiting should terminate within twelve hours. Where the nausea and vomiting continue for a longer period, especially for more than twenty-four hours, it may be accepted as an evidence of beginning peritonitis. Various measures are employed for the relief of these symptoms, among them acetanilid, 1 to 2 grains, every hour until three doses have been given; tincture of nux vomica, 1 or 2 drops every hour; creosote, $\frac{1}{2}$ drop every three or four hours; the administration of a Seidlitz powder, dissolving the blue powder in half a glass of water and dropping the white powder dry upon this, and giving it while it is effervescing, directing the patient to retain it. If she does so, the distention of the stomach causes a portion of it to be carried over into the duodenum, and, when the intestines are pretty well evacuated, the patient is unlikely to continue to suffer from nausea and vomiting. Where the condition is persistent, with more or less distention of the upper part of the abdomen, the stomach-tube should be used, and the stomach washed out with normal salt solution until the water runs clear and free. The patient may then be given a hypodermic injection of morphin. Vomiting at this stage usually indicates peritonitis, and the most effective treatment is to keep the patient moderately under the influence of morphin. The initial dose may be $\frac{1}{8}$ to $\frac{1}{6}$ grain, and subsequently $\frac{1}{16}$ to $\frac{1}{12}$ grain every three hours. During its administration nothing should be given by the mouth. She should be fed

by the rectum, and preferably with normal salt solution. No more effective measure can be employed than continuous instillation of a salt solution into the rectum, as suggested by Murphy, with the patient placed in Fowler's position. (For details, see Vol. III., pp. 775–777.) If an elevation of temperature follows the operation, careful investigation should be made to discover its cause. An examination of the blood should be made, to determine the presence of leukocytosis. The wound and the pelvic cavity are both carefully examined, to determine whether there is any grave cause for the condition. Vomiting may persist until the patient vomits fecal matter. The occurrence of vomiting associated with distention of the abdomen and inability to accomplish the evacuation of the bowels, and especially the vomiting of fecal matter, should lead to reopening of the wound, as not infrequently such symptoms arise from a volvulus or twist in the intestine. Elevation of temperature during convalescence should also be a reason for careful investigation of the field of operation. Any indication of accumulation within the pelvis or thickening around the stump of the uterus where supravaginal hysterectomy has been done, or about the vaginal wound, should be an indication for immediate vaginal puncture. Gauze should be inserted to insure free evacuation of pelvic accumulations.

Operative Injuries.—The bladder, intestines, and the ureter may be injured during the operation. When an opening has been made into the bladder, it should be at once closed with a double row of catgut sutures. Likewise in intestinal wounds the opening should be immediately sutured, and a second row of sutures outside the original should be inserted. The ureter may be cut or ligated during the procedure. When the latter has taken place, and especially the ligation of both ureters, it will lead to absolute unilateral or bilateral failure of urinary secretion. When it is evident that this condition exists from the continued failure to secrete urine, the abdomen should be reopened, the ligatures removed, and the condition of the ureters determined. Occasionally it will be found that the patient is passing urine through the vagina or the vaginal wound. This, of course, indicates that the ureter or the bladder has been injured, and the patient suffers from incontinence. This condition need not require an immediate operation. It is better to allow the convalescence to proceed for a time to see whether the opening may not contract and the discharge cease. Whether the condition exists in the ureter or is in the bladder can be determined by injecting some colored fluid. After injection, if the liquid continues to run clear through the vagina, it is evident that a ureterovaginal fistula exists. In such cases the uterus having been removed, it is a less formidable procedure to make an incision into the bladder through the anterior vaginal wall and use the lower flap of this for insertion into the posterior wall of the vagina, thus slightly shortening the canal and making the point at which the urine enters the vagina a part of the bladder.

If the patient does well, she should be given a generous diet after

a few days. The sutures should be removed from the eighth to the tenth day. When the ventrum is weak, the abdomen should be supported by strips of iodoform gauze passed the greater way around the trunk, and holding in place a small aseptic dressing. She may sit up at the end of two weeks, and at the end of three weeks, if the wound has healed by first intention, she may return home. When the termination is not so favorable, she should be required to remain in bed for a longer time. Stitch abscesses or abscess of the abdominal wall may occasionally occur. Their occurrence causes elevation of temperature, pain, and discomfort. The infected sutures may be much slower in undergoing disintegration where such infection arises, so after a judicious time the sinus should be explored by a hooked instrument, which catches the buried suture and assists in its removal, after which very generally the entire wound heals. Formerly, it was the custom to bury silk or other non-absorbable sutures, and such suppuration continued as long as any portion of the suture remained.

SURGERY OF THE BROAD LIGAMENTS.

The broad ligaments afford a limited field for surgical measures. It is true that the broad ligament may be the seat of ovarian and parovarian cysts and intraligamentary myomata, but the treatment of these conditions is preferably considered under the particular growth. Occasionally there will be found in the broad ligament cystic growths which are independent of any other structure. The origin of these growths, however, must be a question of doubt, as it is not impossible that fibroids which have originally been connected with the uterus have been separated from it and have migrated. A cyst in this situation may be pedunculated, having drawn the broad ligament out by its weight, but more frequently it is situated within the layers of the ligament. The diagnosis of these conditions is rather difficult, and may not be made until the abdomen is opened. Should a growth be discovered in the broad ligament, the latter should be opened and the tumor dissected out, following which all vessels should be carefully secured and the peritoneal surfaces closed. The broad ligament is frequently the seat of infective processes, which may result in extensive extravasation and suppuration. These may have reached the broad ligament through injuries to the vagina or uterus. In some cases it may be through the Fallopian tube. Where possible, it is wise to forestall suppuration by vaginal incision, through which the ligament is spread out and drainage permitted by gauze packing.

SURGERY OF THE FALLOPIAN TUBES.

Inflammation of the Fallopian tubes is the direct result of infection, which, in the majority of cases, comes through the uterus. Its gravity will depend upon the virulence of the infection and the resistance of the patient. The most frequent causes are gonorrhea

and sepsis, and these, with rare exceptions, travel through the uterus. The inflammation may be slight, form simply a catarrhal salpingitis, or be very severe, involving all the structures of the tube. The former is known as the catarrhal and the latter as the suppurative form. In the slight inflammation the condition is superficial, involving the epithelium and the tissue upon which it rests. In the more virulent form it passes rapidly through the epithelium to the deeper structures, causing extensive destruction. In addition to the source of the infection named the right side of the pelvis may be infected from a diseased appendix or a tube, which contains a collection of blood and is adherent to a knuckle of intestine, and may receive infection through the latter. In tuberculous salpingitis the infection may reach the tube either through the uterus, or, more generally, the peritoneum, or possibly the blood. With the entrance of infection there follows swelling of the epithelium, the surface becomes edematous and granular, with infiltration of the deeper structures from inflammatory products. Serous effusion takes place into the tube, with loss of cilia, especially on the free surface, while they may remain between the folds. The epithelium of the tube is well preserved on the surface, even in extensive suppuration. Inflammation of the tube leads at a very early period to irritation of the peritoneum and agglutination of the abdominal end. This is an effort upon the part of nature to obstruct the further progress of the disease. The uterine end becomes closed by swelling, and later by exudate, which collects in the tube. The effusion in the tube may be either serous or purulent, according to the virulence of the infection and the resisting power of the patient. In either cases it is likely to increase, forming, in the one, a serous collection, and in the other, a collection of pus.

Excessive hyperemia of the tubal surface or a partial twisting of its neck may cause rupture of the vessels, and result in an extensive accumulation of blood. The condition is known as hematosalpinx. It is more frequently associated with retrogressive changes in ectopic gestation. When the pedicle of a simple cyst becomes twisted and rapid development occurs as the result of the hemorrhage, which may take place into the sac, and also into the abdominal cavity, it may lead to the suspicion of a ruptured ectopic gestation. Occasionally the swelling of the uterine end is overcome by distention, and the fluid drains into the uterus. When this occurs at frequent intervals, the condition is known as *hydrops tubæ profluens*. The muscular coat of the tube is made up of circular and longitudinal fibers; the contraction of the former, under inflammatory changes, may lead to a number of pockets or cysts, or, when in the longitudinal layer, the tube becomes shortened, the peritoneal coat is pushed over it like the cuff of one's coat over the hand, and the irritation of the peritoneal surfaces leads to the abdominal end becoming closed, forming a sac. Occasionally the contraction is not sufficient to complete the retraction of all the fimbriæ; one or more of these protruding renders leakage from the sac likely to occur. This is a frequent cause for

recurring attacks of peritoneal irritation and slight peritonitis. The small-cell infiltration and thickening of the longitudinal folds not infrequently fill up and obliterate the cavity (Fig. 177). When the inflammation is extensive, the entire structure of the tube may be thus infiltrated, forming a large, hard mass. The longitudinal folds

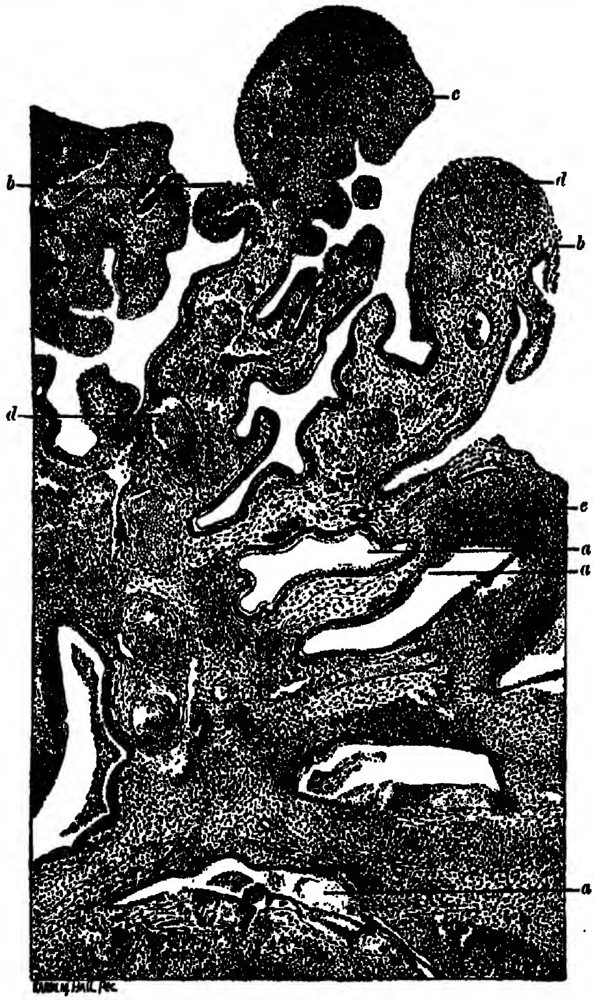
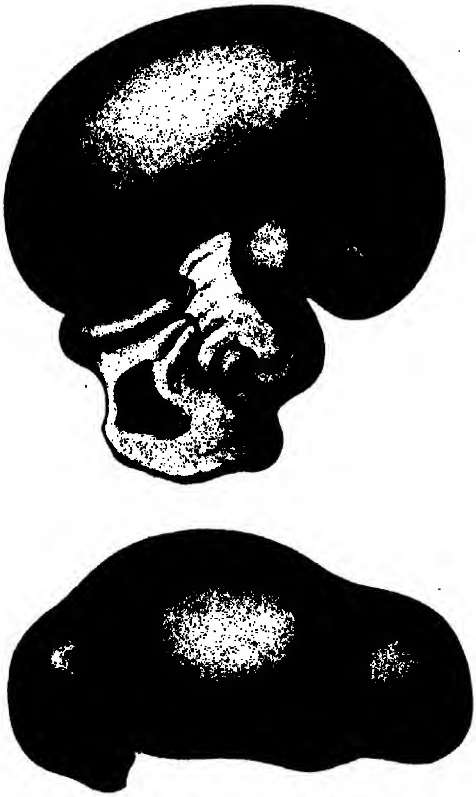


FIG. 177.—SECTION FROM WALL OF PUS-TUBE. (Montgomery.)
a, a, a, Folds matted together, forming gland-like spaces; *b, b*, folds undergoing dissolution; *c*, shows complete desquamation of epithelium covering folds; *d, d*, blood-vessels distended with blood-cells; *e*, leukocytic infiltration.

frequently lose their epithelium and, becoming adherent, simulate distended glands. The tube may become greatly thinned and distended, forming a large cyst known as a hydrosalpinx. This may be freely movable and without adhesions, or may be fixed. Where the inflammation is particularly virulent, the collection within the tube is purulent, the two walls are thickened, the inflammation extends to

the adjacent structures, causing adhesions to the coils of intestine, the omentum, the uterus, the ovary, and the parietal peritoneum (Fig. 178). The tube becoming heavy from inflammation may drop into Douglas' pouch and become adherent to the sigmoid or the side of the rectum. Where pus-collections exist, the distention may lead to perforation of the rectum and the discharge of the contents through the bowel. Such a sac is never completely emptied. It partially empties itself, the pressure is removed, the opening may temporarily close, and the reaccumulation reopens it. Such a course may continue

A



B

FIG. 178.—DISTENDED PUS-TUBES. (Montgomery.)
A, Tube whose pedicle was twisted, sac filled with blood and pus; *B*, right tube filled with pus.

for a period of years or until the strength of the patient is exhausted. Involvement of both tubes may lead to their dropping into Douglas' pouch and their tubal ends coming in contact and becoming adherent, forming one large sac (Fig. 179). The adhesion of the orifice of the tube to the ovary will frequently result in the transudation of the infection and the formation of a tubo-ovarian mass, which may attain to considerable size (Fig. 180). Where a pyosalpinx exists for a long time, the acute inflammatory symptoms subsiding, the more solid portions of its contents are deposited upon the wall of the cyst, and the fluid eventually becomes clear, forming a hydrosalpinx.

Symptoms.—There are no characteristic symptoms of tubal inflammation. The patient who suffers from pain and tenderness over the lower portion of the abdomen, with a certain amount of distention and swelling, tenderness on motion, painful evacuation of the bowels, and marked tenderness during coition, makes it evident that there is inflammatory trouble which has more than likely reached the peritoneum by the Fallopian tubes. The normal tube is scarcely palpable. When it becomes thickened with salpingitis or parenchymatous inflammation, it may be recognized as a more or less well-

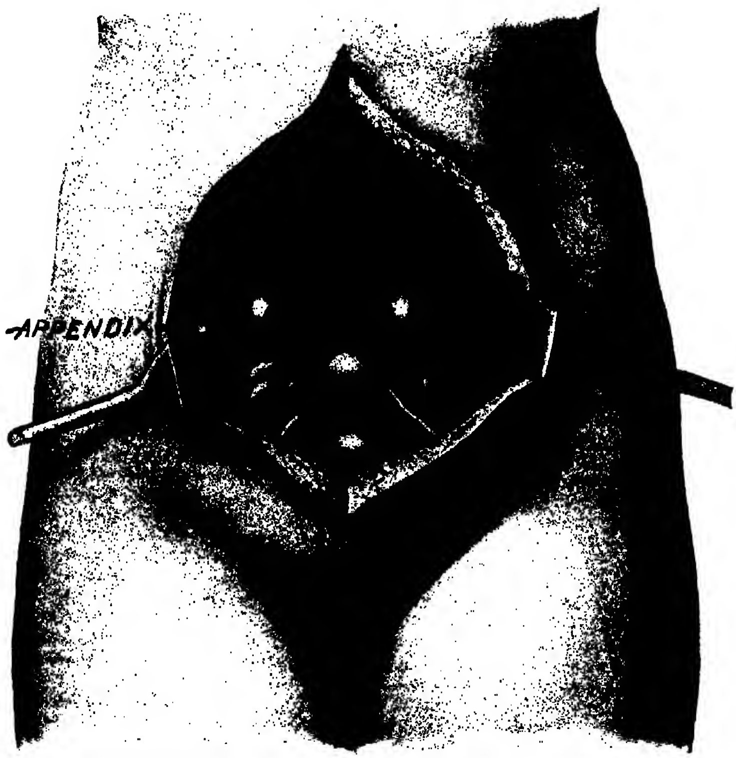


FIG. 179.—DOUBLE PYOSALPINX, WITH ADHESIONS TO THE RECTUM AND UTERUS, AND ON THE RIGHT TO THE APPENDIX. (Montgomery.)

defined and thickened cord, which is extremely sensitive to pressure. The inflamed tube may vary in size from a mere cord to a large, gourd-like mass, or one which resembles a number of sausage links or has the shape of a sweet potato.

Diagnosis.—The recognition by palpation that the uterus is bound down, the mass situated upon either side of it or extending up toward the brim of the pelvis, may be accepted as evidence of the presence of tubal inflammation. This is distinguished from an ovarian cyst by the fact that the latter is more or less spheric, has a distinct pedicle between it and the uterus, while in the tubes the enlargement begins

near to the uterus and increases in extent as they pass upward (Fig. 181). The mass may so encircle the ovary as to make it difficult to determine that the latter organ is not itself partaking in the inflammatory process. A tumor which is retort-shaped, quite movable, is without a doubt a hydrosalpinx, while a pyosalpinx is more likely to be adherent to the surrounding structures (Fig. 182). Not infrequently it may be situated at the side of the pelvis, embedded in a mass of exudation, but more frequently it lies behind the uterus in Douglas' pouch. A tubo-ovarian cyst is recognized by the greater

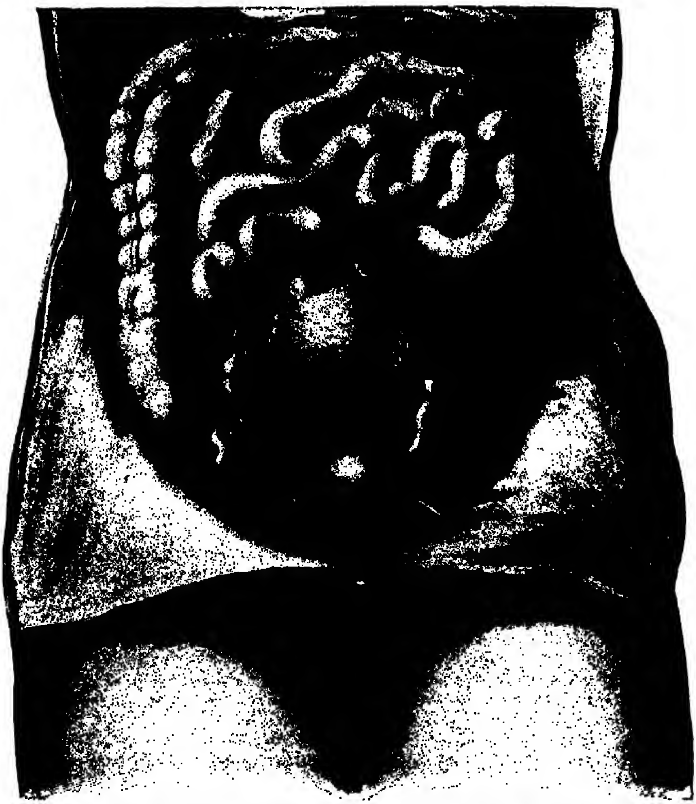


FIG. 180.—DOUBLE TUBO-OVARIAN CYST. (Montgomery.)

increase in size of its external part, forming a more marked bell or retort shape.

In the examination of these patients it is important that the greatest care should be exercised in pressure, as otherwise rupture may occur, and the contents escape into the peritoneal cavity. Unless the contents are sterile, such an escape will be attended with grave danger from the rapid development of a fulminating peritonitis.

Prognosis.—Tubal inflammation should always be considered as attended with grave danger. Even in the mildest forms it is important that the patient should be subjected to treatment, with a view

to its arrest, if possible, before destruction of the function of the tube has occurred. When it is associated with pelvic peritonitis and the infection is virulent, as in the streptococcic form, it may be one of the most dangerous lesions that can confront the surgeon. When associated with disease of the ovaries and extensive suppuration of the

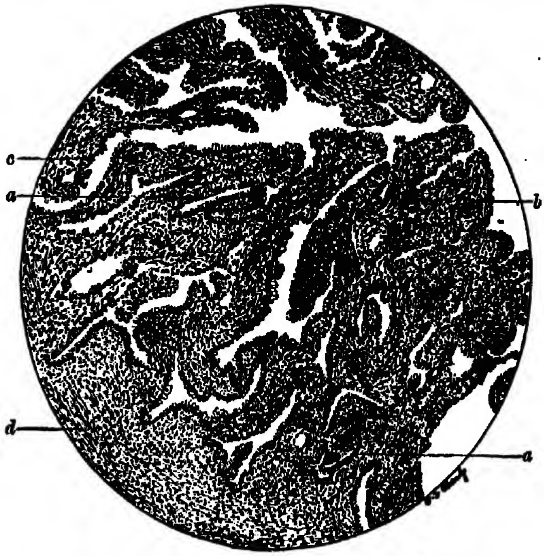


FIG. 181.—CHRONIC SALPINGITIS. (Montgomery.)
a, Union of folds forming gland-like areas; *b*, thickened and retracted fold; *c*, desquamation of epithelium; *d*, hyperplasia of tubal wall.

tube, the possibility of cure in the sense of restoration of function is impossible. Even should the patient recover, she is sexually handicapped for life.

Treatment.—The treatment of tubal disease consists in absolute rest, the application of cold in the form of an ice-bag over the abdomen,

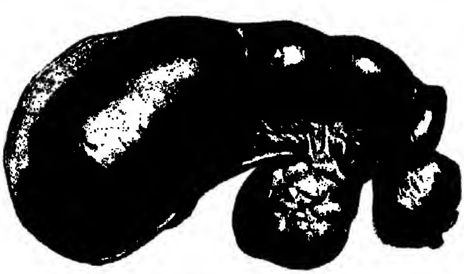


FIG. 182.—HYDROSALPINX. (Montgomery.)

the administration of remedies that will provoke free watery evacuation of the bowels, thus making the intestines drain the inflamed peritoneum, and the restriction of diet to the absolute need to sustain her. It is preferable that operative procedure should be postponed until the subsidence of the more acute attack, unless it is evident

that free effusion has taken place into the peritoneal cavity, or that Douglas' pouch contains collections which are readily accessible through the vagina. In such cases the evacuation of the contents of Douglas' pouch, the opening of pus-sacs, the irrigation of the cavity, and packing it with iodoform gauze will not infrequently serve the purpose of bringing about an arrest of the inflammatory process. In other cases, especially where a number of septa have formed in the tube, forming several sacs, this procedure will be ineffective in estab-

FIG. 183.—REMOVAL OF PORTION OF THE TUBE IN CORNU OF UTERUS.

lishing complete relief. When it is necessary to open the abdomen, or when operating in the intervals, after the subsidence of the acute inflammation, the treatment of the tube will depend upon the changes it has undergone. In some cases the separation of adhesions, milking out of the fluid from the tube, and cleansing the surface will be sufficient to bring about a restoration of health without the sacrifice of tissue. In other cases, where the tube is obstructed and serous effusion is contained within it, the tube may be opened, adhesions

broken up that close its abdominal end, the fimbriæ set free, and in some cases the peritoneum turned back like a cuff over its end and secured by means of sutures, so that the mucous end of the tube will be unobstructed. Where the end of the tube is much diseased, it may be found necessary to resect it, leaving the healthy portion of the tube, uniting its mucous membrane to the peritoneal surface and attaching it to the side of the ovary. This still leaves a channel through which the ovum may enter the uterus. Where the tube is extensively diseased and is the seat of suppuration, it may be necessary to sacrifice one or both tubes. In these cases, if an ovary is in a healthy condition it should be left, dissecting off the tube only, as it is impossible, in any individual case, to determine what influence castration may have upon her subsequent mental life. It makes no difference how little the individual values the possession of children, if she once realizes that she is bereft of the *possibility* of procreation, what she has lost seems to be one of her most valuable possessions. The retention of the ovary favors the continuation of menstruation, and as long as she has this visible evidence of the possibility of procreation, she remains hopeful. Where suppuration exists in the tube, it is wise that the latter should be removed into the cornu of the uterus (Fig. 183) and the raw surfaces united by sutures, using for this purpose continuous chromic catgut, securing with the suture the branches of the uterine and ovarian arteries. Before the abdominal wound is closed, the pelvis should be carefully inspected to see that all hemorrhage is absolutely controlled.

The Fallopian tubes may be the seat of both benign and malignant growths. The benign growths found in the tube are fibroma, fibrocyst, enchondromata, dermoid and small cysts, polypus, and papillomata. These growths in this situation are extremely rare. Sarcoma, carcinoma, and chorio-epithelioma are also found in the tube. These are most frequently secondary, except the latter, which may develop in the tube just the same as it does in the uterus. The recognition of malignant conditions, of course, demands, where possible, the entire removal of the tube, and when secondary, of the ovary and the uterus also.

SURGERY OF THE OVARIES.

Inflammation of the ovary occurs in two forms: inflammation of the structure of the organ and of its periphery. The former is designated as *oophoritis*, and the latter as *peri-oophoritis*. Hyperemia or congestion of the ovary may result from infection. When we consider that the ovary undergoes rupture of a Graafian follicle, with the discharge of its contents each month or oftener, and this is followed by a collection of blood which undergoes a retrogressive process, it can be easily understood how infection may reach the ovary through the Fallopian tube and an abscess result. Not infrequently do we find that collections of blood-clots take place in the organ, known as an *ovarian apoplexy*, or a larger collection of blood—an *ovarian hematoma*.

The ovary may be completely destroyed, forming a mere shell or sac resembling an ordinary cyst.

Oöphoritis is an inflammation of the structure of the ovary, which may be either acute or chronic, gonorrheal or septic. It is characterized by all the signs of inflammation, such as swelling, engorgement of blood, increase in size of the blood-vessels, extravasation of blood, and the formation of pus. The latter may involve only a small part of the ovary, or the entire organ may be taken up by the abscess. The ovary may be infected through the Fallopian tube, by way of the lymphatics or blood-vessels, or by contact with a knuckle of intestine or with an inflamed appendix. The abscess may involve the ovary alone, with a similar condition in the corresponding tube, the suppurating ovaries generally becoming adherent to the surrounding structures. If the walls are thick, the pus may remain relatively quiescent, and be the cause only of continued ill health. The suppurating ovary is generally adherent to the surrounding structures and can drain through the intestine, the bladder, or the vagina. The cavity thus evacuated may become contracted and ultimately disappear. An abscess in the ovary, however, is not always associated with peri-oöphoritis. Peri-oöphoritis results in marked thickening of the envelop of the ovary, the tunica albuginea, which becomes so firm and resistant that it is not readily ruptured by the maturing Graafian follicle, so that an ovary thus infected is likely to contain a number of small cysts which have evidently failed to rupture. This leads to cystic degeneration of the organ. Chronic oöphoritis is not infrequently associated with mumps. Peri-oöphoritis is the result of inflammation which has extended from the Fallopian tube, involving the surface of the ovary, causing it to be bound down and covered with a mass of adhesions. It may be a part of a widely extended inflammatory process, is generally associated with fixation of the end of the tube; not infrequently the uterus is also adherent. This inflammation interferes with the normal function of the ovary so that it is impossible for an ovum to escape from the fully matured Graafian follicle. The ovary is generally situated in Douglas' pouch, where it is fixed between the rectum and the uterus, and subject to pressure from a distended rectum, and injured by the impinging male organ during coition, so that the life of the individual is attended with severe discomfort.

Symptoms.—Like disease of the tubes, oöphoritis exhibits no characteristic symptoms. Even in acute cases there is nothing present which can be said to be a positive indication of the ovarian lesion. In the less severe forms, however, we recognize symptoms which can be justly attributed to ovarian disease. Of these, pain is the only constant symptom in all varieties of pelvic inflammation. It is more likely to be felt in peri-oöphoritis a week or ten days prior to menstruation. At this time, the ovary becomes engorged with blood and the pressure of the adhesions upon the distended ovary produces distressing pain. This pain may be felt in the inguinal region over

the ovary, more possibly as an ache. It is also not infrequently found that the corresponding mammary gland is the seat of a severe pain. The pain in the ovary is aggravated by pressure through the vagina or the rectum. There are no characteristic disturbances of menstruation, although it is found in cystic degeneration of the ovary which is associated with chronic oöphoritis that irregular bleeding and prolonged menstruation are frequently associated.

Diagnosis.—The infection rarely confines itself to the ovary, so that the phenomena present are modified by the surrounding inflammation. The recognition, by bimanual palpation, of a tender body, somewhat enlarged, but retaining the shape of the ovary, confirms the diagnosis. The presence of adhesions or exudates will fix the organ in one position. It should not be forgotten, however, that pain in the inguinal region is not necessarily the result of ovarian disease, as not infrequently points of pain which can be covered by a silver dollar in this region are due to neurotic conditions rather than to actual ovarian disease.

Treatment.—Rest in bed, abstemious diet, saline purgatives, and cold applications should be considered as the proper treatment in the acute conditions. Arterial tension may be reduced by administration of tincture of aconite in small, frequently repeated doses. Where it is evident that suppuration exists, it is better that immediate operation should be done and the infected organ removed. In chronic oöphoritis with enlargement of the ovary and thickening of its tunica albuginea, resection of a portion of the ovary will be attended with very great benefit. This brings about a more active metabolism, by which a portion of the inflammatory exudate is absorbed, and the ovary is better able subsequently to perform its functions. In peri-oöphoritis it is quite a point that the ovary should be set free, the bands of adhesions fixing it broken up, and especially bands which are attached to the intestine; the peristaltic action of the latter drags and pulls upon the ovary, greatly increasing the nervous irritation. When the ovarian ligament is elongated and the ovary shows a disposition to drop into Douglas' pouch, it is well to break through the thin part of the broad ligament between the Fallopian tube and round ligament and push the ovary through the opening, closing it by suture. This places the ovary upon the ligament between the tube and the round ligament and prevents further displacement. When the tube and the ovary are infected, the proper procedure is to remove them entirely.

Parovarian Tumors.—This name is given to tumors or cysts which have their origin in the parovarium or organ of Rosenmüller (Vol. I., Fig. 223, p. 828). This is a structure which is found in the broad ligament, and consists of eight or ten fine tubes running vertically to the long axis of the ovary and entering the para-oöphoron or hilum. They are the remains of the Wolffian body. Their ends, remote from the ovary, are joined by a horizontal tube which runs parallel with its long axis. This is called the duct of Gärtner. The

parovarian cysts develop out of the vertical tubes. These cysts are sometimes called simple broad-ligament cysts, and it is asserted by Doran that they develop in the broad ligament independent of the parovarium. These tumors are distinguished by the fact that the ovary is attached to the side of the cyst, the Fallopian tube stretched across its top, and if the tumor is large, the tube is elongated and the mesosalpinx thickened. As they develop in the broad ligament, the peritoneum is easily stripped off. The contents are clear, limpid, straw colored, with a specific gravity of about 1010, and the sac is generally unilocular. Bland-Sutton asserts that they form about 10 per cent. of the tumors ordinarily diagnosed as ovarian cysts. These cysts when ruptured or punctured sometimes disappear and the sac becomes obliterated. I have seen such growths, however, which were tapped a number of times. When they attain to a considerable size, they spread out the broad ligament and the parietal peritoneum, and that covering the tumor may become adherent and so firmly united that the cyst can be enucleated without entering the peritoneal cavity. The fluid contained within the tumor is not irritating, so that when it ruptures into the peritoneum there is a free discharge of urine for a few days, when the trouble subsides. As the cyst is loosely attached to the peritoneal covering, the growth may frequently be enucleated without the sacrifice of the ovary. Occasionally, there will be found papillary vegetations within such a cyst, but they do not modify its clinical history.

Ovarian Cysts.—Ovarian tumors display a greater tendency to malignant degeneration than any growths of other organs, and it is difficult to determine in an individual case whether it is malignant or benign. They are divided into cystic and solid, the former, into the simple, proliferating, and dermoid; the latter, into the fibromata, sarcomata, carcinomata, and endotheliomata, and, according to size, into large and small cysts. They may arise in any part of the ovarian structure, as the cortical and medullary or parenchymatous portions of the ovary. They may attain to enormous size, becoming larger than any other growth of the body, and occasionally so large that the body seems but a mere appendage to the tumor. Maritan reported such a cyst which weighed 200 pounds, the woman prior to the operation having weighed 290 pounds. Bullitt removed a tumor weighing 245 pounds, and Spohn, of Texas, one of 328 pounds, and the patient recovered. The solid tumors are much less frequent than the cystic. The latter are irregular and spheric; the surface is a bluish-white or a glistening white color. Cysts are further divided into unilocular or single cysts and multilocular, where a number of smaller cysts exist. Careful examination of the former will show that not infrequently smaller cysts are situated within the walls. The contents of these cysts vary greatly. Indeed, the different cysts in the same tumor may show radically different contents. In the unilocular the contents are usually clear and limpid, and in the multilocular, thick, viscid, and glue-like. The small cysts are follicular cysts,

cysts of the corpus luteum, and tubo-ovarian cysts. The large are glandular proliferating, papillary proliferating, and dermoid.

The *simple* or *follicular cysts* are unilocular, dilated follicles, generally multiple and small. Fifteen or twenty of these may be found in one ovary. These may project in the wall or lie embedded in the stroma. They were formerly considered the source of larger ovarian cysts, but they rarely cause the ovary to attain a size greater than the fist. The contents are a clear, occasionally blood-stained fluid, with a specific gravity of 1005 to 1020. The cyst-wall is a thin-walled, transparent membrane, covered with columnar epithelium. These cysts are undoubtedly unruptured Graafian follicles. They rarely give rise to symptoms.

Cysts of the corpus luteum are unilocular cysts the size of a pigeon's egg, occasionally as large as an apple. The cyst-wall is comparatively thick, lined by a yellow, apparently folded membrane. This distinguishes them from the follicular cysts.

Tubo-ovarian cysts are cysts which are made up of the tube and ovary. When the orifice of the tube becomes agglutinated to the surface of the ovary by previous inflammation, a cyst in the ovary may have its walls gradually thinned until it ruptures into the tube, and the sac subsequently is made up of the tube and ovary. They sometimes attain to the size of a man's head.

Glandular Proliferating Cysts.—The glandular cyst makes up the great majority of ovarian tumors, and may vary in size from an egg to that of the largest tumor, may fill the abdomen, and encroach upon the thoracic viscera. The surface of the cyst is a pearly white; the thinner portions are purple, green, or black, according to their contents. The term proliferating is applied to those which are highly organized and abundantly supplied with blood-vessels. The term proligerous is applied to cysts that have the faculty of budding or generating new cysts from within the original wall. The tumor, as it increases in size, stretches out its attachment to the broad ligament, and when this becomes elongated, it is known as a pedicle. Some cysts are without a pedicle, and these are most frequently of the intraligamentous variety, *i. e.*, developing in the broad ligament. The tumor pedicle consists of the ovarian ligament, which has become stretched and undergone hyperplasia, and the meso-ovarium or attachment to the broad ligament, and upon this the tube is generally situated to a slight degree. The tube in some cases may be very greatly elongated, and is generally removed with the tumor. The pedicle may vary in length from 4 cm. to 20 cm., and in breadth from 2 cm. to 12 cm., or it may be entirely absent. When the development of the ovary begins toward its hilum, it may spread out the broad ligament and thus form a subserous cyst. Such a tumor is firmly fixed in the pelvis, pushes the peritoneum off from the uterus, and invades the space between it and the bladder or rectum and not infrequently the uterus may be spread out upon its surface. These glandular tumors are divided into areolar, unilocular, and multilocular

cysts. An areolar cyst consists of a number of small cysts with thick, well-developed, and vascular stroma. A number of these cysts may rupture and form a considerable sized one, or the tumor may consist of a number of very small masses, none of which is larger than a plum. The unilocular cysts often attain to an enormous size, but close examination of the wall indicates their previous division into numerous smaller cysts, so that it is quite probable that all the unilocular cysts have originated from the multilocular. Multilocular cysts contain a number of cysts which vary in size. As they increase in size, the pressure of their septa leads to their rupture, and frequently there will be found remnants of the wall between the different cysts. In the larger cysts the epithelium undergoes degenerative changes, disturbance of nutrition through thinning of the intervening walls, and the epithelium may entirely disappear from the wall of the larger cysts. Some of these may have papillary growths upon one side of the cyst, especially that side toward the hilum of the ovary. The contents of the cyst vary greatly in their color and consistency—in some almost colorless, straw colored, green, purple, or black, thin or thick, viscid or gelatinous. At times the contents of the cyst are so thick and viscid that it has the consistency of jelly and has to be ladled out of the cavity.

Papillary Proliferating Cysts.—These cysts may exist as a distinct form or be a complication of the glandular. In this particular form of cyst, its inner wall is studded with vegetations which are a proliferation of the connective tissue. They may attain to considerable size or be very small, and the vegetations as they develop lead to the rupture of the sac and the escape of its contents into the peritoneal cavity. Where this takes place, the peritoneum becomes infected with the growths. The entire cavity, the parietal peritoneum and that of the intestines, may be studded with these masses. Not infrequently they grow over the uterus. These tumors may sometimes attain to considerable size, but more frequently they rupture early. Following the rupture, the vegetations grow rapidly, covering over the structures, and they may then undergo calcareous change, forming chalk-like masses looking like ferns, are readily broken off, and do not bleed. After rupture has occurred and the implantation taken place upon the peritoneum, the abdomen may be greatly distended from ascites and a mass be found in one or other side of the uterus. This may be a very small mass or a considerable sized tumor, and usually is quite adherent. Sometimes, indeed, the inflammatory exudate is so extensive that the tumor becomes completely buried beneath it.

Dermoid Tumors.—Dermoid growths of the ovary are usually of moderate size, rarely attaining a size greater than that of the head of a child, unless it is a mixed growth consisting of glandular and dermoid elements. In these growths the wall of the sac is usually quite thick. The tumor often contains various structures of the human body, such as teeth, hair, muscle, skin, sebaceous glands, bone, and fatty material. In the sac, mixed with the hair, are frequently found

large quantities of sebaceous material. This is acid in reaction and extremely irritating, so that its escape into the peritoneal cavity may be productive of severe peritonitis. It is well, for this reason, that these growths should be removed entire without puncture. The dermoid cyst may exist for a long period of time; it is found in young children and in women ninety years of age. Not infrequently the fatty material may be found to be in the form of balls. Sometimes the wall of these sacs will be filled with calcareous material. The pedicles may become twisted, and the tumor have lost its original relations, being nurtured through adhesions to the omentum or intestines.

Solid growths of the ovary are much less frequent than those of the cystic variety. They consist of fibromyomata, sarcomata, and carcinomata.

Fibromyoma of the ovary is a tumor usually of moderate size, is quite firm and hard, and, from its weight, may become impacted in the pelvis and give rise to irritation of the rectum, and from the irritation of the peritoneum may not infrequently be the cause of severe ascites.

Sarcoma of the ovary forms a tumor resembling the fibroid. It is smoother upon its surface, not so firm and dense, and may be either of the round or the spindle-cell variety. The latter form is more solid. The round-cell sarcoma forms a large, soft mass which develops rapidly. Not infrequently we may have the glandular proliferatng cyst and sarcoma mixed, the masses or nodules of sarcomatous disease being situated in the structure of the glandular cyst.

Carcinoma of the ovary occurs more frequently than sarcoma. Investigation of ovarian cysts has shown that at least 20 per cent. of them are malignant. The cyst-wall becomes infiltrated, and the disease gradually extends to the surrounding structures.

For the etiology and progress of ovarian growths see Vol. I., p. 828.

Ovarian growths attain to considerable size without producing any symptoms whatever. If the tumor is freely movable after it attains a size sufficient to fill up the pelvis, it rises out of it and rests upon the brim of the pelvis. If the tumor, however, is adherent within the pelvis, as it increases in size it makes pressure upon the rectum and bladder, causing marked discomfort in both. As ovarian tumors increase in size they make pressure against the abdominal viscera, crowd up the intestines and stomach against the diaphragm, interfere with the heart's action, decrease the capacity of the lungs, interfere with the circulation through the abdominal viscera, and produce marked disturbance of nutrition. The patient becomes emaciated, while the abdominal distention increases. The face looks haggard, sallow, and drawn, presenting a condition known as *facies ovariana.* When the tumor attains to very large size, it may so interfere with the return circulation as to bring about dropsy of the lower extremities, and the patient presents an appearance as if the growth was completely sapping her vitality.

Complications.—An ovarian cyst may be complicated by *ascites.*

This may result, as we have already seen, from rupture of a papillary ovarian cyst and the infection of the peritoneum, producing a general peritonitis with serous effusion. It may be produced by necrotic changes in the growth, which becomes a foreign body and thus produces a general peritonitis. Ascites is more likely to occur where the pedicle has undergone torsion, and especially when the entire tumor becomes necrotic. Another complication is *distention of the pelvis of the kidney*. This is brought about by pressure upon the ureter. This interference with the passage of the urine to the bladder causes the kidney to become greatly distended, but is less frequent in cystic than in solid growths. *Adhesion* between the cyst and the surrounding structures is a rather frequent complication. This may take place in large ovarian cysts as the result of pressure, which causes the loss of vitality of the superficial epithelium. Injury to the surface of the cyst from bruises may cause a localized peritonitis and the formation of adhesions. The adhesions may occur between the intestines or omentum and the surface of the tumor, between the tumor and the abdominal parietes, or they may exist in the pelvis. Any condition which leads to infection results in the formation of adhesions. When a tumor is situated in the pelvis or abdomen, so that *pressure* is made upon a knuckle or coil of intestine, the changes thus induced may result in adhesions through which the infection enters the cyst and causes its rupture into the adherent coil of intestines. In this way portions of the contents of the cyst may escape into the intestine and the intestinal contents into the cyst, producing serious inflammatory changes. I have seen dermoid cysts thus opening into the intestines with a coil of hair projecting into the intestinal cavity.

Torsion of the Pedicle.—This is not of infrequent occurrence with a cyst of moderate size and a long pedicle. The changes of position of the patient may lead to rotation of the cyst and a partial rotation at once to obstruction of the venous or the arterial circulation. Thus blood is pumped into the growth which cannot get out and leads to serous effusion, even to rupture of blood-vessels, and to the escape of blood into the tumor, and through its walls into the peritoneal cavity. When the torsion is more complete, gangrene sets in, the tumor becomes a necrotic body, and at once degenerates, and general peritonitis with extensive serous effusion results. Such a condition should be suspected whenever the growth which has existed for some length of time takes on rapid increase in size. The pulse is rapid, the patient experiences shortness of breath, she has difficulty in breathing in the recumbent position, looks anxious, and her condition is apparently critical. Inflammation and suppuration of the sac are complications which are much less frequently present than formerly, when it was customary to draw off the contents of such tumors by paracentesis. The employment of the trocar permitted the introduction of infection to the cyst, which would result in inflammation and not infrequently in suppuration.

Inflammation and Suppuration.—An inflamed cyst the seat of inflammation and suppuration is extremely sensitive to pressure; the patient has a rapid pulse and a temperature elevated and markedly fluctuating. The patient may frequently have severe chills. When suppuration has occurred, the temperature varies considerably each day. The patient loses her appetite, becomes rapidly emaciated, has hectic flush of the cheeks, and presents all the symptoms of a very grave condition.

Rupture of a Cystic Tumor.—Rupture of a cyst may occur as the result of injury, a fall, or of necrotic changes in the cyst-wall. It is indicated by more or less pain in the abdomen, by tenderness over the abdomen, and by change in the contour of the tumor. Instead of being prominent in the vertical direction, the tumor becomes flattened, spreads out from side to side, and the patient presents more the appearance of a woman with ascites. In a small or unilocular cyst the fluid is rapidly absorbed by the peritoneum, and the patient for a few days passes inordinate quantities of urine, when the tumor apparently disappears. This is particularly true in parovarian cysts, when the cysts may undergo a certain amount of inflammation which leads to their obliteration. When the fluid is irritating, thick, and viscid, it at once develops a localized peritonitis. Both the parietal and visceral peritoneum becomes coated over with the thick, viscid material which cannot be scraped off. The abdomen is flattened and gives a sensation of fluctuation and resonance on percussion, with change of the position of the body, which would lead the investigator to suppose that he is dealing with ascites.

Pregnancy.—The degeneration of the ovary or of both ovaries by the formation of cysts, unless it destroys the entire ovarian stroma, need not prevent the occurrence of conception. Indeed, pregnancy is not an unusual complication of ovarian cyst. The result of the pregnancy will depend somewhat upon the situation and size of the growth. In those cases in which the tumor is situated within the pelvis, filling it, and pushing the uterus upward, it may very greatly interfere with the nutrition of the pregnant uterus, thus endangering the offspring prior to its maturity, and endangering also the life of the patient. When the tumor is small and readily movable, it may be pushed out of the pelvis, allowing the uterus to drop into it, and thus prevent the return of the cyst to a position where it would be a cause of obstruction. In cases, however, in which the ovary is fixed in the pelvis, we have to consider other methods of procedure. A cyst fixed in the pelvis, which cannot be displaced, will necessarily prevent the delivery of the patient, even though the head of the child could be delivered after the reduction of the size of the cyst; its pressure would so devitalize the growth as to lead to serious consequences. In all such cases we have to consider the possibility of interference during the progress of the pregnancy. Experience teaches that, if necessary, abdominal section may be done during a pregnancy without interference with its progress, and will greatly

influence the comfort of the patient subsequently. The tumor at times may be so large that there is not sufficient room for it and the enlarging uterus. Small growths situated in the abdomen and above the pelvis may be permitted to remain until the patient recovers from the full effects of the gestation. In those cases in which the tumor is situated in the pelvis the other alternative to operation for removal of the tumor would be to do a Cesarean section.

Diagnosis.—The ovarian cyst is recognized by bimanual palpation. The mass fills up the abdomen, and we are able to determine its outline, that the contents are fluid by its fluctuation, that it is contained within a sac rather than free in the abdominal cavity by the general outline of the distention, the cervical diameter being the greatest in the cyst, the transverse diameter in the free fluid. In considering the diagnosis we have to determine, first, whether the distention is due to an abdominal tumor. In determining this the differential diagnosis must be made in ventral hernia, tympanites, fecal accumulation, distended bladder, ascites, and localized peritoneal effusion, all of which conditions give rise to distention of the abdomen simulating an abdominal tumor.

Ventral hernia is a protrusion of the intestine or omentum through other than the natural openings in the abdominal wall. It most frequently follows an abdominal incision where faulty methods have been employed in closing the wound. Such a distention produces a tumor which is resonant over its surface, and which, under systematic and careful manipulation, may be reduced in size or may even entirely disappear. When it has thus been pushed back into the abdomen, the opening through which it made its exit is readily recognizable. A tumor more nearly simulating the ovarian cyst will be found in cases in which there is a diastasis of the recti muscles, leaving the intestines to fall through, covered only by the skin and peritoneum. The intestinal coils can be recognized, and their vermicular motion seen through this thin covering. Percussion over the mass is everywhere resonant.

Tympanites is a distention of the intestine from gas, and is generally not persistent. It is usually associated with some inflammatory condition within the abdomen. Percussion of such a distention affords everywhere a resonant sound, and this resonance does not change with the position of the patient.

Fecal Accumulation.—The accumulation of fecal matter within the large intestine may sometimes form a mass that resembles a tumor and may be mistaken for it. Careful examination, however, discloses that pressure upon such a mass will leave an indentation which remains. When the physician is at all in doubt, the administration of purgatives, by clearing out the alimentary canal, makes the diagnosis certain.

Distended Bladder.—In low fevers it is not of unusual occurrence to find a tumor in the lower part of the abdomen which will be entirely dispelled by the introduction of a catheter. It is not of unusual

occurrence for a young resident physician, seeing such a case, to call the attention of his chief to a supposed ovarian cyst, as the tumor is in the median line, pushing up the intestines, so that resonance is situated around and above it, while dulness occurs over the tumor. The vaginal examination of such a patient discloses the bulging of the anterior wall of the vagina, and the catheter should be employed; when, if it is a distended bladder, it will at once be revealed.

Ascites.—Ascites is not infrequently mistaken for an ovarian cyst. We have in ascites and ovarian cyst a common symptom, fluctuation. The fluctuation in ascites extends further back in the flank. In an ovarian cyst the projection of the vertebræ forward lifts the tumor out of the flank, so that fluctuation does not extend back. In percussion over such a projection in ascites it is found that the intestines, being lighter than the fluid in which they float, rise to the surface, causing an area of resonance over the tumor, while in fluid that is contained within a cyst the zone of resonance is on either side or above the tumor. In ascites this zone of resonance changes with the change of position of the patient, while in ovarian cyst the position of the patient makes no difference, the resonance and dulness remaining the same.

Localized Peritoneal Effusion.—This is more difficult to determine from ovarian cyst. It is generally situated at one side of the abdomen; it is irregular in its outline, and is associated with symptoms indicating a previous inflammatory condition of the pelvis. Its most frequent cause is a tuberculous peritonitis. In some cases it is necessary to make an exploratory incision in order to arrive at an accurate diagnosis.

Now, having satisfied ourselves by exclusion that the abdominal condition is an abdominal tumor, we are, secondly, to determine whether it is an ovarian growth. An ovarian growth differs in size according to the length of time it is in existence and the variety of cyst with which we are confronted. It may be confounded with pregnancy, with hydramnios, with extra-uterine pregnancy, uterine myomata, retroperitoneal tumors, and other abdominal collections.

Pregnancy.—One would suppose that pregnancy would be unlikely to be mistaken for an ovarian cyst, and yet cases have been tapped with the supposition that an ovarian cyst existed, to find that the pregnant uterus had been the site of operation. In pregnancy the general appearance of the patient and the history of amenorrhea are of importance, although it occasionally occurs that menstruation continues regularly during the progress of the pregnancy; the physical examination will disclose that the tumor is situated within the uterus; that it is not pedunculated, and also we may feel uterine contractions, portions of the body of the fetus, and we may also be able to recognize fetal heart-sounds, all of which exclude an ovarian cyst.

Hydramnios.—The large and sudden accumulation of fluid within the amniotic sac which is known as hydramnios is an occasional occurrence of pregnancy. The marked distention, the sense of

fluctuation, the thin wall through which the fluctuation is distinct, are all symptoms which lead to the supposition of an ovarian cyst. Vaginal examination, however, will disclose the cervix, more or less taken up by the accumulation. Sometimes, indeed, the cervix will be widely dilated. The patient, being in an upright position, pressure against the protruding membrane in the external os may afford the sensation of ballottement.

Extra-uterine Pregnancy.—In an advanced stage, where the fetus has continued to live, this condition may readily be mistaken for an ovarian growth. The uterus will be found attached to the tumor, possibly in front of or beneath it. The sensation of fluctuation will be recognized, but careful palpation will also disclose portions of the fetus as resisting masses within the sac.

Uterine Myomata.—As these growths are generally firm and resisting, there would not seem to be any excuse for their being confounded with an ovarian cyst, but not infrequently it will be found that a myoma has become edematous from some interference with its nutrition. It becomes greatly increased in size, and presents a sense of fluctuation so distinct as to lead the investigator to believe that it is a cystic tumor. Bimanual palpation, however, in such a growth discloses its association with the uterus by a more or less well-defined pedicle, or in some cases the entire uterus may be taken up with the growth and its cervix form the pedicle.

Retroperitoneal Tumors.—Retroperitoneal tumors may be situated in the pelvis or upon one side of the abdomen. Unless large, careful investigation will disclose the intestinal resonance over the surface of the tumor, but in many cases the diagnosis is determined only after the abdomen is opened.

Other abdominal collections, such as physometra, hydrometra, and hematometra, are distentions of the uterus. In the first, the uterus is distended with air; in the second, with serous fluid, and in the third, with blood. Bimanual palpation in all these cases discloses that the uterus is a part of the tumor, and hence determines its character.

The third subject for diagnosis is the relation of the tumor to the surrounding parts: thus, the tumor, more or less fixed by adhesions, is situated within the abdominal cavity. These adhesions may exist between the tumor and the anterior parietes, or the pelvic structures, the omentum, or coils of intestine. The mobility of the tumor with each inspiration and expiration affords some idea as to the presence of adhesions. The ability to push the tumor up from the pelvis into the abdominal cavity also affords the certainty that, if adhesions exist, they must be long and not a severe obstruction. Another condition to be recognized is torsion of the pedicle. This, as we have already seen, leads to rapid increase of the size of the tumor from obstruction of its venous circulation and the failure to interfere with the more rigid vessels, the arteries. The tumor rapidly increases in size, or the twisting may be so marked as to interfere with the circula-

tion, causing the tumor to become a foreign body, and a peritonitis with serous effusion to follow.

Variety of the Tumor.—As we have already seen, ovarian tumors are divided into glandular proliferating, papillary proliferating, and dermoid tumors, in addition to which is also the parovarian cyst. The largest tumors are the glandular proliferating. These are not infrequently multilocular. That there are a number of cysts can be determined by the short wave of fluctuation, the irregular and nodular feel of the growth, and its large size. Papillary proliferating growths are smaller in size, are likely to undergo early rupture, and to be complicated by ascites. The pelvic examination of such a patient will disclose more or less induration or infiltration on either side of the uterus, with an ascitic accumulation filling the abdominal cavity. The dermoid tumor is generally a small tumor; it is rounded, spheric in shape, has some elasticity, but no fluctuation.

Treatment.—The former treatment of ovarian growths consisted in the frequently repeated evacuation of their contents. Even after the removal of the growth became popular it was felt that at least two or three tappings should be done preliminary to a radical operation. Such procedures endanger the patient through the possibility of the escape of the viscid and irritating contents into the peritoneal cavity. It is now recognized that the only justifiable treatment for such a tumor is its removal, which operation, from long usage, is known as ovariotomy.

Ovariotomy.—This operation was first performed by Ephraim McDowell, a physician in the back woods of Kentucky. He did the operation nine times before he reported it, and his report slumbered for a long time before it had any influence upon the profession. The successful work of the Atlees, of Pennsylvania, Dunlap, of Ohio, and Kimball, of Massachusetts, in this country, and that of Clay, in England, led to the acceptance of ovariotomy as a justifiable procedure. With the advent of antiseptic measures and later aseptic treatment surgeons very soon forgot their fear of the peritoneum, and tumors which were formerly considered as not large enough to demand their removal are now subjected as a routine measure to ovariotomy. The indications for this operation may be considered as the recognition of the presence of an ovarian tumor, however large or small it may be. When we remember that 20 per cent. of ovarian cysts are malignant; when we are unable to determine in the early stage the presence of a papillary growth which may rupture and lead to secondary implantation, the importance of the early radical removal of the growth must be appreciated.

Contraindications.—The only contraindications to the removal of an ovarian cyst is complication of the condition by the presence of some constitutional state, such as a serious heart lesion or an advanced pulmonary tuberculosis which would render the patient unlikely to recover, and would soon terminate her life even if the growth were removed.

Preparatory Treatment.—In the performance of an operation so grave as ovariotomy must necessarily be in a patient who has a large ovarian cyst, it is desirable that she should be placed in the best possible condition for a favorable termination. It is important, then, that the alimentary canal should be cleared of all long-retained masses which would present opportunity for possible infection following the operation. Then, too, the thorough cleansing of the alimentary canal enables us to use it subsequently for drainage by repeated purging. The urine should be investigated, and, where deficient, excretion should be promoted by the administration of plenty of water. The patient should be thoroughly bathed, thus improving elimination by the skin. It may be important, at times, to administer remedies to stimulate the circulation and in every way put the patient in as good condition as possible prior to subjecting her to the operation.

Instruments.—The operator should be provided with a scalpel, two pairs of scissors, two pairs of tissue forceps, a dozen good-sized hemostats, a couple of pedicle clamps, ligature carrier, needle-holder, and needles. It was formerly the rule to also have an ovariotomy trocar. In operating in a private house this instrument may save the room from being soiled by the discharge of the contents of the cyst, but even then the procedure may be managed by making a puncture into the cyst, and the introduction of an ordinary glass nozzle with a rubber tube attached to carry the fluid into the receptacle or vessel. This will serve in the case of unilocular cysts. In the multilocular cyst the trocar is of but little value.

Operation.—The operation consists in first making an incision, about three inches in length, in the median line, about midway between the symphysis and umbilicus. Through this incision the surface of the cyst is explored. The hand may be introduced through the opening, and the presence or absence of adhesions determined. Gauze is packed around the opening, while an assistant makes pressure upon either side of the abdomen, pushing the cyst forward and downward against the abdominal incision. In a unilocular or glandular cyst a puncture is made through the center of the abdominal incision, and a pair of forceps applied on either side of the incision, by which it is drawn well out of the wound, where it is held by the pressure from the assistant. The contents are thus evacuated without entering and soiling the abdominal cavity. In a unilocular cyst the entire cyst may thus be readily drawn through the opening, its pedicle clamped, and the cyst removed. In a multilocular, one of the largest cysts is punctured and its contents evacuated. As the sac is emptied it is drawn out of the wound, and through this sac other cysts may be punctured and emptied until the tumor is sufficiently reduced in size to permit of its being drawn through the incision.

In some of these cases the amount of tissue is so great as to require the extension of the incision upward and downward. As the tumor is withdrawn care is taken to prevent traction upon any adhesions which exist, and to insure their separation. The adhesions may be

separated, where recent, by simply sponging back the adherent structures while the tumor is drawn upon. Where the adhesions are firm and older, it may be necessary to separate them with the finger, tearing the intestines and omentum off from the surface of the tumor. When the adhesions are too rigid to permit of this, they may be separated with the scissors, exercising care to keep close to the uterine sac and injure it, rather than the adherent coils of intestine. Sometimes the adhesion of the intestine is so close to the cyst that it is impossible to remove the latter without injuring the intestine. In these cases we may cut through the cyst-wall, leaving a portion of the cyst like a patch upon the intestine, and the intestinal coils are separated, leaving the adherent portions as small as possible. In separating adhesions, not infrequently it is found that the omentum adherent to the surface of the tumor has exceedingly large vessels, which it is important should be cut between clamps or ligatures before the tumor is withdrawn. As the tumor comes out upon the abdomen separated from all its adhesions, it hangs by a pedicle which we have already described. This pedicle can be clamped by means of a good-sized hemostat or a pedicle forceps. The tumor is cut away, the large vessels ligated, or the stump may be ligated en masse. The peritoneal cavity is carefully inspected, the surface in which adhesions have existed is investigated to see that undue hemorrhage does not take place, the cavity is sponged out, all bleeding vessels tied, gauze pads with which the intestines have been walled off are removed, the presence of all pads that have been used is determined by the count of the nurse and by careful investigation, to see that none is retained within the abdominal cavity. After the pedicle is thus ligated, it is desirable that all raw surfaces should be covered with peritoneum to prevent unfortunate adhesions to the coils of intestine.

The abdominal cavity is thoroughly inspected, and the condition of the other ovary investigated. If this is not done, an ovarian cyst of considerable size will occasionally be overlooked, necessitating the subjection of the patient to a repetition of the operation. Where there has been an escape of fluid from a cyst into the abdominal cavity, it is well to irrigate with normal salt solution. This may wash out clots and portions of viscid material, and thus readily cleanse the cavity. It is not necessary to sponge out all the saline fluid, as the retention of a portion of it renders the patient more comfortable during convalescence. The next step is to close the wound. This I prefer to do with chromic catgut and interrupted silkworm-gut, as follows: First, begin on the outside of the aponeurosis, on the right side of the upper angle of the wound, carry the needle through the aponeurosis, muscular structure and peritoneum, introducing the suture in the peritoneum alone upon the left side of the wound, and thereafter taking up only the peritoneum with each continuous suture, until the lower angle of the wound has been reached, when the suture is brought out through the muscular structure and aponeurosis of the left side; this suture being drawn tightly, so as to close the peri-

toneum, is for the present laid aside. The silkworm-gut sutures are then introduced, carrying them through the skin, superficial and deep fascia, and muscular structure, leaving the peritoneum the only tissue not included. After these have been inserted and their ends secured by hemostats, the original chromic catgut suture is taken up and continued back through the aponeurosis by successive turns until the upper angle of the wound is reached, where the two ends of the suture are tied. The silkworm-gut sutures are then tied, and the edges of the skin between each suture are united by interrupted fine chromic catgut sutures. The wound is washed with alcohol, dried, and a piece of sterile gauze placed around the sutures, the ends of which are left long. These sutures are laid upon the piece of gauze mentioned, and are covered with other gauze pads. Finally, a piece of gauze and cotton pad are placed and secured by tapes attached at one end to the abdominal wall by a piece of adhesive plaster, and, over all, a T-bandage.

Injury of the Bladder.—During this operation the bladder may be opened, as it is frequently adherent and lifted up by the ovarian cyst. When this occurs, it should be sutured at once, the sutures being introduced to, but not through, the vesical mucous membrane. A second row of sutures should be inserted to bring the tissues over this line, both sutures being of chromic catgut.

Injury of the Intestine.—A knuckle of intestine may be torn in the effort to separate it from the cyst. The injured intestine should be at once closed with a suture. Sometimes the intestine will be so injured that it will be necessary to resect a portion of it, when an end-to-end anastomosis may be made by means of the Collins suture, and this supplemented by a peritoneal suture over it.

In intraligamentary ovarian cysts the broad ligament is frequently spread out, and the pressure of the cyst causes the uterus to become very firmly adherent to it, and oftentimes spread out over it. In such a condition it will be necessary to remove the uterus as well as the cyst. It should not be forgotten that the ureter may be closely associated with the cyst, and be endangered in its enucleation. Frequently the ligation of the broad ligament on the opposite side of the uterus, cutting across the cervix, and enucleation of the cyst from below, will enable it to be pulled away from the ureter without its injury.

Drainage.—Formerly it was the custom to drain the peritoneum whenever extensive adhesions existed or the abdominal cavity was soiled by the escape of the cyst contents, especially where they were thick and viscid or had undergone some marked change. In later years drainage has been much less frequently practised, it being a well-recognized fact that the peritoneal cavity is capable of taking care of a moderate amount of foreign material. Very rarely, indeed, a glass drainage-tube is inserted at the lower angle of the wound; this was almost a matter of routine with many men a few years since. In cases in which there has been extensive adhesions or there is

oozing, it is considered better practice to pack the cavity with iodoform gauze. This serves a double purpose, controlling somewhat the tendency to bleed, promoting a more rapid closure of the cavity, and protecting the intestines from coming in contact with raw surfaces, which would necessarily lead to the formation of extensive adhesions and probably result in ileus. One end of this drain or packing is inserted through the opening into the posterior fornix of the vagina, so that it permits the wound to be entirely closed and the packing to be removed through the vagina.

After-treatment.—The after-treatment of operations for the removal of ovarian cysts necessarily depends upon the character of the operation. In ordinary cases nothing more is required than to place the patient in bed and permit her to roll from side to side as her comfort may dictate. Liquids should be denied the patient for a little time, until it is made sure that she will not be nauseated from the anesthetic. Where the patient is shocked and depressed, she should be surrounded by hot-water bottles or bags, and these isolated from contact with the body of the patient by an intervening blanket, and the bottles should be strong and be thoroughly closed, so that no possibility of bursting or leaking exists. The nurse from time to time should investigate to see that these are not displaced by the movements of the patient so that they come in contact with the skin. When the patient is much shocked or depressed, she may be given a hypodermoclysis of salt solution under each breast. Where she has lost much blood and the pulse is feeble, it is preferable to give an intravenous injection of normal salt solution, to which one dram of a 1:1000 solution of adrenal chlorid has been added. Three or four ounces of salt solution may be injected into the bowel every three or four hours, thus maintaining the equilibrium of the blood-pressure. Not infrequently the anesthetic will be followed by nausea and vomiting. A good draught of warm water or bicarbonate of soda and warm water, or aromatic spirits of ammonia followed by hot water, will frequently neutralize the irritation and arrest the nausea. If it does not, the presence of material within the stomach makes the vomiting more easy, and helps to wash out the irritating material.

This can sometimes best be accomplished by a Seidlitz powder, dissolving the bicarbonate of soda or the powder in blue paper in a half-glass of water, then dropping the tartaric acid or powder in white paper dry upon this, and letting the patient drink it down immediately, and directing her to retain it as long as possible. The effervescence continues in the stomach, distends it, and a portion of the material passes through the pylorus. If she does vomit, it washes out the stomach and leaves her more comfortable subsequently. Where the patient has a certain amount of tympanites, with constant retching and vomiting of bitter, foul-smelling material, it usually indicates a beginning peritonitis, and the best thing is the introduction of the stomach-tube to wash out the stomach. If she still continues to vomit, the irrigation should be repeated and the patient placed under the

influence of moderate doses of morphin hypodermically. Absolute rest of the stomach while nutrition is kept up by rectal enemas and hypodermoclysis will oftentimes carry patients through who would die were we to practise the old method of attempted purgation. Where tympanites occurs without much elevation of temperature and effects the lower intestinal tract, it is best relieved by enemas. Those most efficient for this purpose, as increasing the peristalsis, are tincture of asafetida, 2 ounces in 2 gallons of soapsuds, or powdered alum, 1 dram to 2 gallons of warm water. Where the first injection is retained, a second should be given in order to bring about the evacuation of the bowels. Where extensive adhesions have existed, it is well that purgation should begin early. Calomel, $\frac{1}{8}$ grain every ten or fifteen minutes until one or two grains are given, which should be followed with a saline, *e. g.*, magnesium sulphate, 1 ounce, diluted sulphuric acid, 1 dram, syrup of ginger, 6 drams, cinnamon water, sufficient to make 4 ounces, of which a tablespoonful should be given every hour.

When the patient's convalescence is normal and unattended by disturbance of the alimentary tract, she may be given light food at the end of twenty-four hours, and at the end of forty-eight hours a fairly generous diet. She should be kept in the horizontal position for two weeks or longer if she has had disturbed convalescence or conditions which would render union incomplete. The sutures may be removed at the end of eight to ten days. The patient should first be propped up in bed and afterward lifted out into a chair. When her convalescence has been complicated, or she has been very weak and debilitated, the getting up should be gradually instituted, as she may very readily have heart-clot, which would lead to a fatal result. Occasionally, where extensive adhesions have existed, a knuckle of intestine may become obstructed during convalescence, producing ileus. This will be indicated by prolonged and finally fecal vomiting. The latter occurrence is an indication for reopening of the wound in order to set the intestine free. Ordinarily the patient may be permitted to sit up at the end of two weeks. If, for any reason, the union of the wound is likely to be feeble, the abdominal wall should be supported by adhesive straps. The after-effect of the operation on the patient will depend, of course, upon its character. Where both ovaries have been removed, the menses cease and the violence of the inforced climacteric will depend somewhat upon the patient's age. In some cases the symptoms are very slight. In others they may be very marked, producing neurotic changes that may require years before the patient fully recovers from their effects.

ECTOPIC GESTATION.

Ectopic gestation is a pregnancy in which the fecundated ovum develops outside of the uterine cavity. It is divided into tubal, ovarian, and abdominal pregnancy. Tubal pregnancy develops in some portion of the Fallopian tube; ovarian in the ovary, but is

extremely rare. Abdominal pregnancy is secondary to rupture or tubal abortion. It is a question whether the pavement endothelium of the peritoneum is ever capable of affording nutrition to the fecundated ovum, but, after it has once had a start in the tube and been discharged therefrom, the impetus received may enable it to become ingrafted upon the abdominal surface and derive its nutrition from it. Tubal pregnancy is most frequently found in the central portion of the tube; occasionally in the external end, when the tube, and not infrequently the ovary, forms part of the sac-wall and is known as a tubo-ovarian pregnancy. It is still more rare in the uterine end of the tube, when it is designated as an interstitial or cornual pregnancy. It is now generally recognized that the union of the fecundated ovum and spermatozoön takes place either at the abdominal end of the tube or before the ovum has escaped from the Graafian follicle. The ovum thus fecundated is attracted to the tube by the wave-like motion of the cilia, causing a current of fluid down the tube, which draws the ovum into it. This is possibly accelerated by the fact that the end of the tube is connected with the ovary by a long fimbria which has a groove in its surface. This, however, would not account for the fact that normal pregnancy sometimes occurs in a patient who has lost the ovary on the one side and the tube upon the other, so that there must necessarily have been a transmigration of the ovum from the one side of the pelvis to the other in order to reach the uterine cavity. Any condition, then, which renders the course of the ovum into the uterus difficult or delays it increases the possibility of its being arrested and its development in the canal. Inflammatory changes in the Fallopian tube, which lead to a loss of the cilia of the epithelium, are generally accepted as one cause. Probably extensive inflammation of the muscular structure of the tube, decreasing the peristaltic action, is a more effective one. Inflammatory changes in the tube may lead to narrowing of the canal, so that its caliber is not sufficient to admit the further progress of the enlarging ovum or the formation of infundibula by agglutination of the edges of the longitudinal folds. These infundibula are sometimes congenital. Whatever the cause, the fecundated ovum covered with the ectodermal cells or trophoblasts becomes fixed in the tube. It is unable to eat its way into the surface of the tube, as it does into the structure of the uterine mucous membrane, and consequently there is an absence of decidua. As the ovum develops the wall of the tube becomes gradually thinned; its villi may penetrate the surface, making minute perforations upon the peritoneal surface, which may be the source of quite free and continuous bleeding. The caliber of the tube is insufficient to permit the ovum to develop to any marked degree, and it results consequently sooner or later in the rupture of the wall, perforation of the villi, or the escape of the ovum through the abdominal or uterine ends (Fig. 184). The escape from the end of the tube is known as tubal abortion and occurs in those cases in which the ovum develops near the end of the tube. As the ovum increases in

size, it is pushed out and may be entirely or only partially separated from the tube. When it is entirely separated, it becomes a tubal abortion; when only partly, it may become surrounded by the ovary or the parietal peritoneum, and a sac thus become formed, which will permit the further development of the embryo. Rupture of the tube may occur at any time between the third and the twelfth week after conception. The rupture may be incomplete or complete, intraperi-

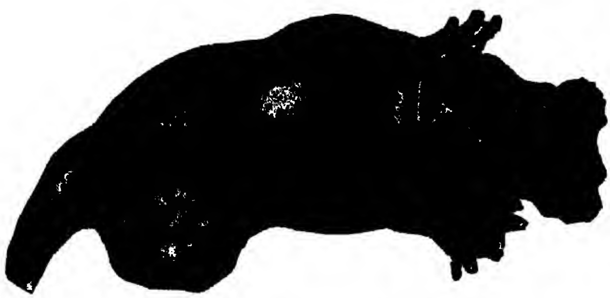


FIG. 184.—TUBAL ABORTION. (Montgomery.)

toneal or extraperitoneal. The incomplete rupture is a simple crack or break in the wall which is at once covered over by plastic exudation which glues up the opening. This may continue to develop until another rupture occurs, and in this way the sac may attain to considerable size. Complete rupture is where the break in the wall of the tube is sufficient to permit the escape of its contents into the abdominal cavity (Fig. 185). The placenta may remain adherent,

FIG. 185.—TUBAL GESTATION. RUPTURE. (Montgomery.)

and the sac-wall be formed by the parietes, the intestines, and the side of the uterus, and thus a new enveloping sac be found in which the fetus may reach full term. Intraperitoneal rupture is usually associated with more or less bleeding. The amount of this will depend, of course, upon the size of the vessels that may have been injured. Thus, where the rupture takes place over the attachment of the placenta, the hemorrhage may be very profuse. In those cases in which the villi grow through the wall of the tube, forming minute

perforations, the hemorrhage may be continuous, and so severe as to cause the patient to be profoundly shocked. Extraperitoneal rupture is rupture through the portion uncovered by peritoneum. The contents escape into the broad ligament, which is spread out by the hemorrhage until the sac is so distended that the pressure antagonizes that of the vessels, and the hemorrhage is then arrested; or the broad ligament may become so tense that it ruptures and causes what is known as a secondary rupture, in contrast to the original rupture of the tube, which is known as primary. A cornual or interstitial pregnancy may rupture either externally, or the uterine end of the tube becomes distended, permitting the exit of the sac into the uterus, where it may continue to develop as a uterine pregnancy, or be thrown off as a uterine abortion. This fortunate termination, however, is exceedingly rare. The most frequent occurrence is its rupture into the peritoneal cavity, which is one of the most grave accidents of ectopic gestation, in that the parts through which the rupture occurs are generally quite vascular, hemorrhage is very severe and rapid, and the termination is generally a fatal one.

Symptoms.—Ectopic gestation in its inception differs very little from that of ordinary pregnancy. The woman has a cessation of menstruation, and the ordinary symptoms indicating pregnancy. As the sac becomes further developed, however, it causes colicky pains and a sensation of more or less discomfort upon one side of the pelvis, an occurrence which should lead the physician to investigate his patient carefully to determine the possibility of an ectopic gestation. This examination should be made with the greatest care, as a thin-walled sac may thus be ruptured, and has, to my knowledge, led to the death of the patient before the physician could get ready for the proper treatment. Where the gravity of these symptoms are not appreciated, the patient has a violent seizure—so violent in some cases that she may drop as if shot. She is faint, and recovers from one attack, to pass into another. The pulse is rapid, feeble, sometimes absent at the wrist; the face is blanched, the lips are pale, and she is covered with a cold, clammy perspiration. In other words, she has all the symptoms of profound shock from internal hemorrhage. Not every case manifests such marked symptoms. In some cases it may be a tearing, grinding, or cutting pain, associated with dizziness and faintness, with the feeling that she must lie down, and is followed by more or less tenderness in the abdomen. This condition some weeks later is associated with elevation of temperature, irregular course of the temperature, possibly chills, and indications of some septic process, in which the patient is likely to have a bloody discharge from the uterus. Casts, shreds, and clots are frequently found in the discharge. The patient thinks that she is undergoing an abortion. In some cases the symptoms thus outlined are followed by increase in the size of the abdomen, an enlargement which goes on until the abdomen attains almost the size of an ordinary pregnancy. She may go into labor or have violent commotion in the abdominal

cavity, and, finally, cessation of such symptoms and the subsequent return of her menstruation, with, however, a more or less continually well-defined enlargement of the abdomen. This enlargement may be localized in one side or be situated in the median line. The enlargement may continue for months or years. The fetal sac and its contents are walled off, and become incrusted with calcareous material, and form a tumor which the patient may carry for an indefinite period, or it may undergo infection from its proximity to the intestine; suppuration may result, which may open into the bladder, intestine, or through the abdominal parietes, through which large quantities of fetal bones are discharged, or the changes in the sac may produce a severe attack of peritonitis.

Physical Signs.—The symptoms determined by physical examination vary according to the stage of the pregnancy, and may be simply a small sac, which can be felt upon one side, in which pulsation is greatly increased, usually prior to its rupture; or the pelvis may be filled with a collection of walled-off material which may consist of blood, or have a developing fetal sac which is recognized as being outside the uterus, possibly implanted upon one side, and has a much thinner envelop than is to be found in an ordinary normal pregnancy.

Diagnosis.—The diagnosis of ectopic gestation may be made—(1) Prior to rupture; (2) at the time of rupture; (3) after rupture; (4) during secondary development of the fetus; (5) after peritonitis; or (6) after suppuration has set in. Not many years ago the possibility of the diagnosis of ectopic gestation prior to rupture was considered impossible, but the increased opportunities for study of this subject through repeated operative work have frequently led to its recognition at this period. If a woman who has been suffering from inflammation of the pelvis, who possibly has given birth to one child and been sterile for several years subsequently, and who passes over a period without the occurrence of menstruation, has the ordinary symptoms of pregnancy and develops more or less discomfort in one side of the pelvis, with, may be, simply a burning sensation, a feeling of colic or pressure which at times amounts to quite severe pain, the occurrence of such a condition should lead to a careful investigation, when it will be found that there is an enlargement of some portion of the tube. The tube is tender to pressure, the vessels in the broad ligament beneath it pulsate with increased force—with much greater force than those upon the opposite side. Such symptoms should lead to the recognition of an ectopic gestation. When the surgeon is still in doubt, he may confirm the suspicion by making an incision through the posterior fornix of the vagina, through which, with the finger, he will be enabled to outline the course of the tube and determine the presence of any enlargement.

At the Time of Rupture.—The presence of the symptoms mentioned and the history of the patient's having had a severe cutting pain in the abdomen, or one of a tearing, agonizing character, with faintness, recurring fainting spells, or of a sudden sensation of weakness and

debility, a frequent feeble pulse, inability to rise or assume the erect position, and a bloody discharge from the uterus, should lead to the diagnosis of an ectopic gestation with rupture. If seen a few hours after this has occurred, there may be found dulness in the lower part of the abdomen, due to accumulation of blood in this region and the floating up of intestine. Palpation rarely enables the physician to determine the condition. A few days later, when the watery portions of the blood are absorbed, the clotted material which fills the pelvis is walled off by plastic adhesions, and a well-defined tumor is recognized. It may occupy Douglas' pouch, or be situated in one or the other broad ligament. Such a patient would have a subnormal temperature in the early stages, and, later, slight elevation.

Secondary development of the fetus would be productive of such symptoms as we have mentioned, and be followed by increasing size of the abdomen, with more or less discomfort from pressure, weight, and the presence of a mass which is situated either to one side or behind the uterus and in which the extremities and body of the fetus may be recognized and later the fetal heart-sounds heard.

Peritonitis may occur as a result of the rupture of an ectopic gestation; the escape of blood into the peritoneal cavity irritates the membrane and causes localized peritonitis in the effort of nature to wall off and exclude this blood accumulation.

Suppuration may take place in the blood that has been walled off in the peritoneal cavity, resulting from infection through a knuckle of intestine in contact with it. It may occur many months after the death of the fetus in its sac and the subsequent discharge of pus and portions of the fetus, especially its bony portions, through a sinus into the viscera or through the abdominal wall.

Treatment.—Ectopic gestation should be considered as a highly dangerous condition, demanding prompt measures when it is recognized prior to rupture. Here an abdominal section should be immediately performed for the removal of the sac and its contents, this being less perilous to the patient than the continuation of the condition. Opinions differ as to the proper treatment of rupture. It is a well-recognized fact that many cases in which rupture of the sac has occurred will recover without operation. The profound shock and the weakening of the circulation therefrom favor the formation of a clot, which may plug the vessel and arrest the hemorrhage, so that a patient in whom death seems imminent may gradually rally and finally recover. This possibility has led a number of men to advocate delay in these cases and operation after the patient has fully recovered from the shock. The only objection to this, however, is that it has been demonstrated that patients do die from the hemorrhage. There is no way of determining in the individual case that the hemorrhage, which possibly has been arrested by the enfeebled circulation, as soon as the vascular tension is recovered, will not drive out the clot and the hemorrhage recur; so I believe it better, even though the patient may be profoundly shocked, to operate at once, employing

measures for restoring the circulation as the operation proceeds. Thus, such a patient should have a vein opened and an intravenous injection of salt solution started with the opening of the abdominal cavity, or direct transfusion of blood may be done. The operator should not spend too much time in the toilet of the peritoneum. The tube should be ligated on its proximal side, and the sac be removed; the mass or larger clots scooped out, the belly filled with salt solution, and the wound closed.

After Rupture.—When the patient has recovered from the shock or shows indications that the hemorrhage will not be severe, the urgency of the operation is no longer great. Even in these cases it is better to evacuate the collection of blood, simply for the reason that its absorption will require a considerable length of time. It is deposited in the lower part of the abdomen in contact with the intestines, or possibly infected tubes, and may be readily infected through the intestinal wall, so that a collection of blood, instead of becoming organized, the watery portion absorbed, and the clot gradually disintegrating and disappearing, becomes infected, and suppuration results. This may keep the patient an invalid for a long period. The fluid may preferably be evacuated (when very recent and there is still danger of hemorrhage) through an abdominal incision. The clot of blood is cleared out, the cavity irrigated with normal salt solution, the sac removed, and the wound closed. When considerable time has transpired between the hemorrhage and the date the patient comes under observation, nature has walled off the blood collection, it is no longer free in the abdominal cavity, but is situated in the most dependent portion, and there separated from the general peritoneum. In such cases an incision through the posterior vaginal fornix will frequently enable the operator to evacuate the collection, and by keeping this open with a gauze drain, the patient may escape the necessity of a more serious operation. In cases, however, in which the collection is very large, it will be found that not only is the blood in the posterior culdesac, but that it also fills up the vesico-uterine space, and is not readily evacuated through the posterior opening. For this reason it will be advisable, when there is reason to believe there is a large collection, to make an abdominal rather than a vaginal incision.

During Secondary Growth of the Fetus.—When the fetus continues to grow after rupture of the sac, it becomes a serious question as to how the case shall be managed. Shall we subject the patient to peril from the continuation of the pregnancy, in order to give the fetus a chance for its life? The fetus of an ectopic gestation is much more frequently the subject of defective development than when it is situated within the uterine cavity. The possibility of deformity and the increased danger to the patient render it undesirable that she should be subjected to such increased peril for the slight possibility of the preservation of a well-developed child. If the fetus, however, has nearly reached the viable age, it may then be well to wait the brief

period necessary to give the child an opportunity to live. The danger from a living placenta must then be considered. The insertion of the placenta may be such as to involve coils of intestine or large vessels, making its removal attended with the most frightful hemorrhage. Where the placenta is situated in the sac, so as to permit the removal of both, that should be the operation of election, but, as has been mentioned, this not infrequently is found to be too serious a procedure. Where the situation of the placenta is such that it cannot be removed, the sac can be packed with gauze, united to the abdominal wound, and thus its treatment conducted extraperitoneally. Under the pressure of the gauze and the changed condition, the placenta may lose its vitality and gradually be destroyed. In other cases, as much of the sac as possible may be removed, what remains ligated near the placenta, the cord removed, and the abdominal wound closed. If the case terminates favorably, the placenta will be gradually absorbed and disappear. If changes take place in the placenta and sac, the material may then be evacuated through a vaginal incision. In peritonitis the indication is to make an incision over the affected structures, wall off the intestines and abdominal cavity by a thick layer of gauze, and, where conditions will permit, to remove the diseased structures, followed either by vaginal or abdominal drainage with gauze, closing the remainder of the wound. Such a patient may be placed in Fowler's position, with the Murphy treatment of slow irrigation of the rectum.

Operation After Death of the Fetus.—The removal of the fetus and the placenta some time after death has taken place is attended with much less danger for the reason that the latter, being no longer living, is more readily separated and without the fear of hemorrhage. The sac when it remains for a length of time may undergo calcareous alteration, become very greatly thickened, and its removal is often attended with great difficulty. A mummified fetus or one which has undergone maceration or fatty change may be removed. The sac when not readily removed may be attached to the abdominal wall and drained and its cavity thus finally obliterated. In suppuration of the sac and discharge of the bones of the fetus, the proper plan of procedure is to enlarge the opening and remove the collection of pus and the bony skeleton. When it is not readily accomplished, the opening should be maintained until its contents are completely evacuated.

STERILITY IN THE FEMALE.

Sterility may be defined as inability on the part of the woman to conceive, or having conceived, to bring forth a living child. Sterility is said to be absolute when the woman is unable to conceive, relative when conception has occurred, and she has been unable to produce it alive. Absolute sterility may be either congenital or acquired: congenital, when due to a defective development which renders her unable to perform her functions; acquired, when it results from the

presence of some diseased condition. It is denominated as primary sterility when the patient has never been able to conceive, secondary when she has once conceived and is unable to repeat it. When a woman conceives but is unable to carry the pregnancy to full term, it is known as comparative sterility. A healthy woman living in wedlock through the greater part of her child-bearing period should give birth to ten children.

It becomes a question as to when a woman should be denominated as sterile. The average time after marriage before the birth of the first child is about seventeen months, and but 25 per cent. of married women bear the first child after four years of marriage. When a woman is married for three years and has not become pregnant, she is recognized as sterile. In the study of this subject there are several factors which must be regarded as essential to conception. These are, first, the production of healthy spermatozoa; second, the production of healthy ova; third, the union of the spermatozoa with the ovum, thus stimulating segmentation; fourth, the implantation of the fertilized ovum in the uterine mucous membrane.

The first of these conditions is dependent upon the healthy state of the male. The large number of cases in which, from the previous existence of gonorrhea or metastasis of mumps, or developmental conditions which render the male unable to furnish the fecundating material, make it important that the condition of the husband should be carefully investigated before the wife is condemned as sterile and subjected to any operative measure for its correction. Unfortunately, many of the cases of acquired absolute sterility of the wife are the result of previous attacks of gonorrhea in the husband. Every gynecologist of long experience has but to consult his record of patients to be impressed with the number of suffering women who date their ill health to marriage, having previously never known a sick day, and what a large proportion of these have been unfruitful! The second essential factor, the production of healthy ova, is an impossibility where the ovaries are absent and in some cases of defective ovaries. Not infrequently, the ovaries are the seat of chronic inflammation, either from long-continued hyperemia or through infection, which results in peri-oöphoritis, binding down and fixing the ovaries. The thickened tunic of the ovary does not give way before the developing Graafian follicle, and, as a consequence, the latter does not rupture, and conception is rendered impossible. Third, the production of healthy spermatozoa and healthy ova is ineffectual unless the two can be properly associated, as their favorable union is necessary for the production of the initial process, known as segmentation. Investigations have disclosed that the cells of the human body are provided with a certain definite number of what are called chromosomes, and the ovum and spermatozoön each contain one-half of this number. Their union consequently completes the cell and promotes its development and growth. But in order to permit of their union, properly fitted to maintain their proper functions, it is important that the

structures through which they pass should be in a healthy condition. An absent uterus or absent tubes, an obstructed vagina, or of any portion of the genital tract acquired through inflammatory changes, can prevent this union, and consequently prove a barrier to conception. Both gonorrhea and puerperal sepsis lead to the destruction of the channels of communication, and consequently obstruct the process. It has been seen that a result of disordered conditions of the passageways leads to arrest of the fecundated ovum in its transmission to its proper resting place within the uterine cavity, and to a development en route which becomes extremely perilous to both producer and the product. It is a well-established fact that the spermatozoön makes its way through the female genital tract by its own propulsive power, and must have favorable conditions for this progress. It is true that it can pass through narrow channels which cannot be subsequently traversed by the fecundated ovum, though a normal condition of the secretions of the canal is probably as essential as a patulous canal. A plug of viscid mucus from cervical catarrh filling the external os may prove an invincible barrier to the most vigorous spermatozoön. These organisms thrive best and are most vigorous in an alkaline secretion, consequently an increase in the acidity of the vaginal secretion may inhibit further activity or render them so feeble as to make them ineffective factors for vigorous production. It is quite probable that this condition is an explanation for sterility in those addicted to high living and the use of alcohol.

Finally, the ovum having become fecundated, must be implanted in the uterine mucous membrane. As it passes along the Fallopian tube it becomes roughened by the formation of ectodermal cells or trophoblasts, producing vegetations or villi which, when it reaches the uterus, enables it to sink or eat its way into the mucous membrane, and there become embedded. Any change in this membrane as a result of chronic inflammation renders it unfavorable for the successful implantation or for the subsequent proper nutrition of the developing ovum. It may become partially implanted, and, subsequently, as it enlarges, drag away from the surface, receiving so little nutrition as to be imperfectly developed, and is finally discharged as a foreign body. As a result of diseased conditions, degenerative processes take place in the enveloping membrane or in the placenta, and render it unable to afford a sufficient amount of nutrition for the full development of the fetus, so that in varying stages of its progress it loses its vitality, becomes separated, and is thrown off.

Diagnosis.—The mere fact that a patient has failed to give birth to children is not of itself a sufficient indication that she cannot produce, as the possibility of sterility must be judged by the anxiety of the individual for offspring, and its existence may be artificial rather than absolute, as where means are employed for the prevention of conception. The cause of sterility in a woman desirous of having children must be determined by careful investigation. Physical examination will disclose the condition of the uterus, the possible

normal size of the ovaries, the presence of any inflammatory exudate, or conditions within the pelvis which would preclude the possibility of conception. The record of the patient will be of advantage, as the previous existence of inflammatory conditions, a history of protracted illness associated with profuse leukorrheal discharge which came on suddenly, attended with more or less burning of the external parts during urination, pain and tenderness in the pelvis, would all indicate the probability of an infectious process. As has been mentioned, the male should be examined and the character of his secretions determined. Not infrequently spermatozoa active in an alkaline secretion have their activity inhibited by the very acid secretion of the vagina, which prevents their reaching the deeper structures in an active state. The position of the uterus, as in retroflexion or in acute anteflexion, will decrease the probability of conception. A very profuse discharge, especially a plug of mucus situated in the cervix, may be a greater hindrance than the anteflexion. A woman suffering from interstitial endometritis from which she has profuse bleeding lessens the probability of pregnancy. Women who are very fleshy, who put on flesh rapidly, in whom menstruation is very slight or absent, are less prone to conception. In such cases ovulation probably does not take place, the ovaries being inactive as a result of the fatty changes.

Treatment.—The treatment of sterility will depend upon its cause. Absence of the ovaries, defective small tubes, rudimentary uteri are conditions which cannot be overcome by any plan of treatment. Premature menopause or the accumulation of fat can sometimes be overcome by the employment of increased exercise and the administration of potassium iodid in combination with thyroid extract, in order to decrease the fat formation. In chronic inflammation of the ovary, where the ovum is unable to make its escape, the condition may sometimes be remedied by resection of a portion of the ovarian structure, which brings about a change in its tunic, in the absorption of inflammatory material, and permits conception to occur. A striking case comes to my mind of a patient whom I saw some years ago in consultation, in which an ovary was removed for a tumor said to be a sarcoma by an excellent pathologist. A number of punctures were made in the remaining one, in a young woman who had been married some years without becoming pregnant. She had not only been sterile, but had not menstruated for several years. Soon after the operation she began to menstruate, and shortly after the administration of thyroid extract become pregnant, and has since had three children. Fixation of the tubes and ovaries by inflammatory exudate can sometimes be overcome either by abdominal or vaginal incision, through which adhesions are broken up, the ends of the tubes set free, and the channel of communication reopened. Diseased conditions of the uterus can frequently be overcome by curetting that organ, followed by local applications which decrease the inflammation, improve the condition of the mucous membrane, and render it more

fit to perform its functions. Occasionally a sea voyage or prolonged separation of the parties, thus insuring sexual rest, will prove effective.

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CHAPTER LXXII.

SURGICAL TECHNIC.

By John H. Gibbon, M. D.,

PHILADELPHIA.

ANTISEPSIS AND ASEPSIS.

The wonderful progress of surgery during the past thirty years has only been possible through the practice of, first, an antiseptic, and, later, an aseptic technic. The introduction of the aseptic technic has been the greatest factor in producing the change which has taken place in surgery during this period. The growth and perfection of aseptic technic have been of gradual evolution, and is not yet complete. The present-day students of medicine can have no conception of what the practice of surgery was thirty years ago. In no similar period of time has so great a change been wrought in the principles and practice of our art. It is not only comparable to, but surpasses, the change which was brought about by the introduction of anesthetics.

Antisepsis was first introduced, and its practical application described, by Lord Lister, then Mr. Lister, whose first contribution on the subject appeared in the London "Lancet" in 1867. It is true that others preceded Lister in the use of antiseptics and in the promulgation of the "germ theory" of wound infection, but the credit of setting the subject before the medical profession in a practical way belongs to Lister. Bassi, Semmelweiss, Jules Lamaire, and Bottini all antedated the Englishman in the use of carbolic acid and bichlorid of mercury, and deserve due credit for their contributions, but it was Lister who impressed the profession with the microbic origin of wound infection and the method of successfully combating it.

Certain of the ancients and many others throughout the history of surgery used antiseptics empirically, and for centuries certain drugs were held to be great flesh-producers and wound-healers. There were, however, always a few in every age who entertained the more rational view, which to-day is so prevalent, that incised and other clean wounds will heal of themselves in most instances, and that the application of chemicals only retards the healing. Among these were Bombast, sixteenth century, François Arcæus, 1574, Wiseman, 1692, and many others. Although they did not understand the value of surgical cleanliness, they may be classed as the aseptic surgeons of their time, in contradistinction to those who washed their wounds out with strong chemicals and applied healing salves and lotions. It is evident then that much which underlies our present method of treating wounds is

not really new. It was the proof that suppuration of wounds was the result of microbic infection which made the great turning-point in the history of surgery (1880). At first it was supposed that these pus-producing micro-organisms made their entrance into the wound from the atmosphere, and Lister and others made the most elaborate apparatus for purifying the air about wounds during operations and dressings. Knowing that micro-organisms produced infection, it was natural that Lister should suppose that they existed in the atmosphere. Fig. 186, from Cheyne's "Antiseptic Surgery" (1882), shows not alone the use of the carbolic spray, but also gives us some idea, when compared with

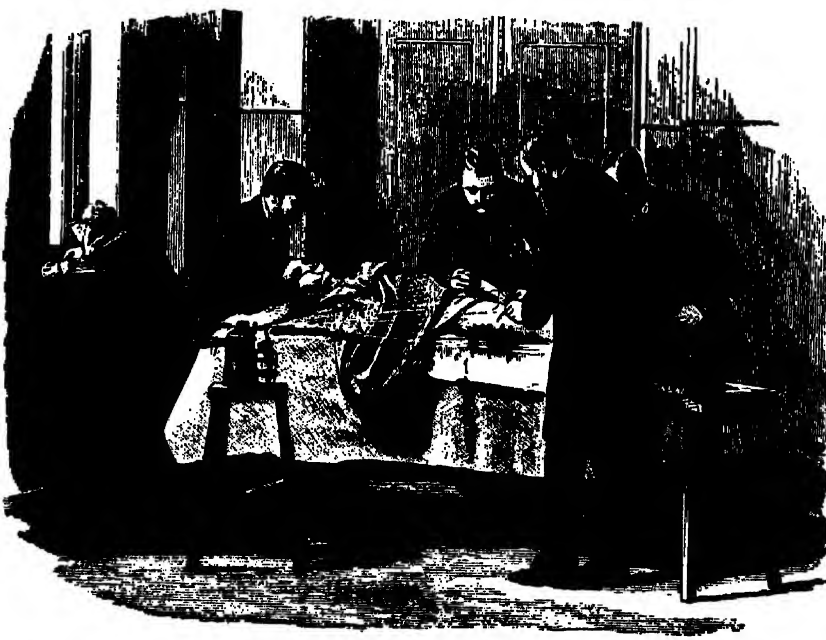

FIG. 186.—REPRESENTING THE GENERAL ARRANGEMENT OF SURGEON, ASSISTANTS, TOWELS, SPRAY, ETC., IN AN OPERATION PERFORMED WITH (SUPPOSED) COMPLETE ASEPTIC (ANTISEPTIC) PRECAUTIONS (1882). (W. Watson Cheyne.)

a modern operation, of the change which has taken place in our technic during twenty-five years.

The introduction of subcutaneous surgery in the early part of the nineteenth century was the result of this fear of contact with the atmosphere, as was also the use of collodion and other dressings which were used at the same period for the purpose of excluding air. The objection to these dressings, which sealed the wound, was that there was no escape for the discharges, and, therefore, in 1866 Jules Guérin developed an apparatus for pumping out the discharge, and with it the air. At various times before and after this period a number of surgeons practised the introduction of other gases as a substitute for atmospheric air. Among those which were experimented with and used to some extent were oxygen, hydrogen, nitrogen, and carbonic acid gas. The use of

oxygen in this way has been revived, and is now practised by some surgeons. Reference to its use is made later. While the French and English were working at the exclusion of air, the Germans, Bartscher and Vezin,[2] were employing the open treatment of wounds with better success, and in the treatment of large granulating areas, such as result from burns, exposure to the air is a well-recognized treatment at the present time.

Koch, early in the eighties showed very conclusively that pyogenic organisms seldom found their entrance into a wound from the atmospheric air, and that, on the contrary, the oxygen of the air was especially

Fig. 187.—The Present-day Operating Room. Compare with that of 1882.

detrimental to the anaërobic organisms. He also pointed out that sunlight had a retarding effect on the propagation of germs. It is due then largely to this work that surgeons gave up the idea that their wound infections came from contact with the atmosphere.

The intelligent use of antiseptics based on the germ theory was first practised and described by Jules Lemaire, who in 1860 published a paper on "Coal-tar Saponin." This preparation contained saponin, alcohol, carbolic acid, benzin, and naphtalin. It was used extensively in the treatment of wounds, with excellent results. Cheyne says of Lemaire that he was "undoubtedly the first who, recognizing that theory (germ theory of putrefaction), applied it to practice." He is careful, however, to state, and does so most explicitly, that Lemaire's

work in no way should detract from the credit which is due to Lister, as the former had no system about his use of antiseptics, although he did believe strongly in the germ theory. Lister's work was carried on entirely independently of any knowledge of Lemaire's experiments. Lister,[3] in a letter to the "Lancet," states that he never made any claim to the original use of carbolic acid, but that the "methods of its employment with the view of pretecting the reparatory processes from disturbance by external agency" was original. To him is due the credit not only of formulating a method of using antiseptics in wounds, but also of showing the great necessity for sterilizing ligatures and instruments. What he had done is readily shown by the following statement by Cheyne:

"The development of his system in his own hands has already been traced. Mr. Lister's writings have stimulated surgeons to the study of the whole subject, and have led to the introduction of improvements in every detail of wound treatment. These improvements, acting on better principles, have brought even the older methods to a high state of perfection, and numerous researches have since been made which have enabled us to reduce to order and show the true principles underlying the various attempts at wound treatment which had been previously carried out."

Cleanliness alone and the use of antiseptics in the wounds alone were tried before, and have been tried since the introduction of the Listerian method, but they have always failed, as we at the present time can readily understand. The whole history of this interesting subject is told in Mr. Cheyne's book, which the reader will find most entertaining.

A. G. Gerster[4] published one of the first comprehensive volumes in this country dealing with the antiseptic treatment of wounds, and it was a potent factor in popularizing the method.

Asepsis, as it is at present understood and practiced, indicates a condition of absolute sterility the result of the use of mechanical cleansing, antiseptics, or heat, or all three. An aseptic operation, therefore, means one in which all the instruments, sutures, ligatures, dressings, the field of operation, the surgeon's hands, and everything, in fact, coming in direct or indirect contact with the wound, have been thoroughly sterilized, and in which no antiseptic solutions are used during the progress of the operation. Aseptic surgery is the natural outcome of Lister's work, and has grown and is still growing in perfection and in the extent of its practice. The ideal operation to-day is an aseptic and not an antiseptic one. American surgeons have done as much as those of any other country, if not even more, to perfect aseptic technic, and this technic is practised more extensively to-day in America than in any other country.

The great advantage of aseptic over antiseptic surgery is to-day questioned by practically no man doing active surgical work. A small volume published by Hunter Robb[5] in 1894, and another by Carl Beck[6] in 1895, dealing with aseptic surgical technic, put this subject in a comprehensive light before the American profession, and it has grown

rapidly in popularity and practice ever since. It is extremely doubtful whether even in infected wounds strong antiseptic solutions exercise the retarding effect on the infection that was once supposed. Aside from the very detrimential effect which they have upon the tissue-cells, it is a question whether they really reach the source of the infection, which is often most active at a deeper plane than the solution can possibly reach; for instance, where there is an extensive slough, the antiseptic solution can certainly do nothing but destroy those organisms which may be on the surface. The irritation resulting from the strong antiseptic solutions probably are more harmful than helpful in many of these cases. Free incision and thorough drainage, which allow the access of the oxygen-containing atmosphere, are probably more important than irrigation with an antiseptic solution. A small opening in infected wounds, and the injection of antiseptic solutions, is not to be compared to free incision, good drainage, and the application of an aseptic dressing. Cleanliness and the aseptic habit in operating upon even the most septic cases should be conscientiously adhered to.

It is to be regretted that our science has not yet reached the point where pyogenic infections may be surely and successfully combated by the internal or hypodermatic administration of some antiseptic agent. Certain specific serums are now being employed with success in the treatment of infections, such as diphtheria, but this work is yet in its infancy. The question of serum therapy in the treatment of surgical infections is elsewhere dealt with, and a simple reference to it at this point is all that is pertinent. The valuable work of Wright and others, based on the opsonic index of the blood, is a pretty clear indication of the direction from which new light can be expected.

Sources of Wound Infection.—By far the most common source of wound infection is the hands of the surgeon and his assistants. The patient's skin also may be the source of the infection. The Staphylococcus epidermidis albus (Welch) is the organism which is most often responsible for the infection. Infected sutures, ligatures, instruments, and dressings are frequent sources of infection, but we should not fall into the habit of attributing our infections to these until we have absolutely ruled out the possibility of the infection having arisen from our own hands or those of our assistants or nurses. The perspiration from the surgeon's face or hands occasionally produces infection, also the saliva which escapes from the mouth during talking. Atmospheric infection of wounds during the course of an operation is of doubtful occurrence. Infection during subsequent dressings is not so apt to take place as at the time of operation, but it may occur unless the strictest aseptic precautions are exercised. Certain predisposition on the part of the patient renders him more liable to infection; this particularly applies to such constitutional conditions as syphilis, alcoholism, Bright's disease, and diabetes. In fact, anything which lowers the resistance of the tissues by diminishing the bactericidal quality of the blood increases the risks of infection. Certain infections are rendered more likely through an hereditary predisposition; this is

well illustrated in tuberculosis. The occupation of the patient may render him more liable to infection—for instance, the risk a morocco worker runs of developing anthrax. It has been suggested that certain races are more predisposed to infection than are others. This, however, is open to some question, as it is probable that the predisposition can be accounted for by other circumstances, such as the patient's surroundings and habits of life. Climate undoubtedly influences infection. In a dry climate, especially at a high altitude, infection is not so frequent as it is in damp atmospheres and in the unhealthy, squalid quarters of a crowded city.

Methods of Preventing and Overcoming Infection.—In the modern aseptic operating room germicides and antiseptics do not play so important a part as they formerly did. This is largely due to the fact that heat is used wherever possible in the preparation of sutures, ligatures, dressings, instruments, etc., and the fact that in uninfected tissues no antiseptic solutions are employed. It must also be remembered that the germicidal agents possess the disadvantage of exercising a more or less destructive action on the body-cells, and consequently their use is not warranted in clean wounds. We still, however, meet with infected wounds sufficiently often to render the use of these agents necessary.

Heat is the most valuable of all sterilizing agents, its only drawback being that it is not universally applicable. Wherever possible, it should be employed in preference to chemical agents. It can be employed either as moist or as dry heat. Moist heat is a much more efficacious germicide than dry heat, destroying the organisms at a much lower temperature. Boiling water at a temperature of 212° F. will destroy nearly instantaneously all pus-producing organisms. Spores, however, require a moist heat of 284° F., kept up for at least half an hour. A dry heat of 212° F. will not destroy pus-producing organisms under an hour and a half, and spores will live for three hours at a dry temperature of 284° F. Although moist heat is very much quicker and more satisfactory in its action, yet it is often inconvenient to employ it in the sterilization of gowns, towels, operating suits, etc. Sterilization by heat has been greatly facilitated by the introduction of the autoclave, by means of which a very high temperature under pressure can be obtained. This is the most satisfactory method of sterilizing dressings, towels, sheets, operating suits, and aprons. A similar and less expensive method of sterilizing these articles is by the use of one of the simple steam sterilizers which are sold by all dealers. In an emergency an ordinary bake-oven can be employed as a sterilizer. It is best, however, where the temperature cannot be estimated, to boil the articles and dry them between sheets moistened with bichlorid solution.

Bichlorid of Mercury.—Among the chemical germicides there is none more universally employed than the bichlorid of mercury. It is actively germicidal in strengths of from 1 : 1000 to 1 : 10,000; stronger solutions are rarely called for in the treatment of wounds, but may be employed for the sterilization of glassware, trays, basins, etc. As a

lotion and for the sterilization of the skin, a strength of 1 : 2000 is sufficient. As a douche, the bichlorid may be employed in a 1: 2000 to 1 : 6000 solution, and solutions of from 1 : 6000 to 1 : 10,000 may be employed in the bladder or on the conjunctiva. There is no excuse for using bichlorid solution in the abdomen; its irritating and poisonous qualities outweigh any supposed good it may do. When used on subcutaneous tissues, an albuminate of mercury is formed; this, however, can be prevented to some extent by combining tartaric acid with the bichlorid. Chlorid of ammonium or tartaric acid is also combined with the bichlorid of mercury to render it more soluble. All antiseptic solutions, especially for use in wounds, should be fresh and warm. This has been rendered easy by the use of the tablets sold by all druggists. The bichlorid tablet in most common use contains 7½ grains, which, added to a pint of water, makes a solution of 1 : 1000. Bichlorid solution of this strength will destroy all pus-producing organisms. Anthrax spores, however, are very resistant. Among the objections to the use of this agent is its irritant action on healthy cells. When applied in too strong a solution on a delicate skin, or even when a weak solution is covered by some impermeable material, like oiled silk or waxed paper, a marked dermatitis is apt to develop. Particular care should be exercised to avoid this during the preparation of a patient for an operation; we have seen a child come to the operating room with so marked a dermatitis that operation had to be postponed. It is also a deadly poison, and is rapidly absorbed by mucous and serous membranes; because of this fact it is rarely used in serous lined cavities, and only in the weaker solutions in mucous lined cavities, such as the vagina. Fatal mistakes have been made from injecting into the rectum a solution intended as a douche. When used in a wound, it always excites an excessive amount of secretion. This agent does not disinfect feces because of the presence of hydrogen sulphid. Most of the tablets put up by the manufacturing chemists have some anilin dye in them, so as to color the solution and thus render its being mistaken for plain water unlikely. The greatest care should be exercised in the use of these tablets in solutions to prevent mistakes. The fatal mistake has often been made of supposing them to be lithia tablets or tablets for making a nasal douche or mouth-wash. As the bichlorid tarnishes all metal instruments, it cannot be employed for their sterilization. The symptoms of bichlorid poisoning are salivation, painful and tender gums, cramps in the abdomen, and diarrhea. Should these symptoms develop, the source of the poisoning should be sought, and any remaining solution evacuated—if in the rectum, by enema, or if in the stomach, by the stomach-tube. In an acute poisoning from bichlorid solution in the stomach or rectum the whites of a number of eggs should be promptly swallowed or injected.

Biniodid of mercury is extensively employed in Great Britain, and may be used in the same strengths as the bichlorid. "It is a more powerful germicide, while it is less irritative, and it neither forms a mercuric albuminate nor tarnishes metal instruments."[7]

Carbolic Acid.—Carbolic acid, a coal-tar derivative, although known as early as 1834, was not used as an antiseptic until about the beginning of the antiseptic era, but soon became the mainstay of this method of wound treatment. It is germicidal in solutions of from 1 : 20 to 1 : 40. The weaker solutions are not germicidal, and even those of the strengths given do not destroy spores promptly. Pure carbolic acid is destructive to all bacteria, and is also equally destructive to the tissue; its action on the tissue can be limited, however, by following its application promptly with pure alcohol. In this way it has been employed for the destruction of lining membrane of old abscess cavities. It is extensively used in the sterilization of rubber instruments and those with wooden handles. The great objection to carbolic acid is its local irritant effect on the tissues. Even a weak solution, if covered with some impermeable material like oiled silk or wax paper, may produce gangrene; scores of cases of gangrene from the indiscriminate use of carbolic acid in the hands of the laity have been reported, and we have seen the loss of several fingers where it has been improperly used. The preparation known as phenol sodique is extensively used by the laity, and we have seen serious dermatitis and gangrene caused by the indiscriminate use of too strong solutions of this agent. Carbolic acid also produces a systemic poisoning through absorption. One of the first symptoms noticed from such absorption is irritation of the urinary tract and carboluria. This poisoning is more apt to take place when the weaker solutions are used than where the pure acid is used, as the destruction produced by the pure acid prevents its absorption. The effect of carbolic acid upon the urine is to cause it to become smoky a short time after it is voided. The urine shows a complete absence or diminution of the sulphates, and albumin is generally present. When these symptoms present themselves, the use of carbolic acid should be at once stopped, and the administration of sulphate of soda and atropin begun. If the condition has lasted for any length of time and the patient is weak and exhausted, stimulants are indicated.

Lysol is a saponified phenol, and possesses some germicidal power; it is used in solutions of from 1 to 3 per cent.

Creolin is mildly germicidal, and is extensively used as a vaginal disinfectant in from 2 to 4 per cent. solutions. Both of these agents (lysol and creolin) act very much as carbolic acid, but neither possesses the former's irritating qualities.

Formaldehyd gas is an active germicide, and very valuable as a disinfectant. It is used in the shape of *formalin*, which is a 40 per cent. solution of the gas in water. This agent is very irritating to the normal tissues in the stronger solutions, but a 2 per cent. solution of formalin may be used for the sterilization of the hands, instruments, etc. The formaldehyd fumes are employed for the disinfection of clothing, rooms, bedding, etc., and also for the sterilization of catheters. The fumes of the gas are very irritating to the mucous membrane, and when this agent is used for the disinfection of rooms, every crevice and crack must be tightly sealed to prevent the escape of the gas.

Glutol is a formalin gelatin which has been extensively used in the treatment of granulating wounds.

Boric acid is a mild antiseptic, but is not actively germicidal. A solution of boric acid, 10 grains to the ounce, is most useful in inflammations of the mucous membranes, such as the conjunctiva and bladder. In the form of an ointment it is also quite extensively employed.

Salicylic acid is an antiseptic of value. It is used generally in the form of a 10 per cent. ointment. It is but slightly soluble in water. In the form of a soap, in combination with sulphur or alone, it is used in inflammatory affections of the skin.

Thiersch's solution is a combination of boric and salicylic acids (boric acid, 1 grain; salicylic acid, 6 grains, to one ounce of water), and is more actively germicidal than either the boric or salicylic solutions alone. It is non-toxic and non-irritant.

Chlorid of zinc in 10 per cent. solution is occasionally used in very dirty and sloughing wounds, such as result from cancerous ulceration. Care should be taken to remove the excess of the solution, as it is very irritating.

Iodin possesses more germicidal property than was at one time supposed. Senn[8] states that it is probably the most powerful antipyogenic known. He uses a solution of $\frac{1}{2}$ of 1 per cent. for irrigation, and $\frac{1}{4}$ of 1 per cent. for dressing. Iodin is being extensively used at present for the sterilization and hardening of catgut. In tuberculous lesions the iodin solutions are particularly advantageous.

Iodoform is an agent which hinders, but does not arrest, the growth of bacteria. It stimulates granulation, relieves pain, and prevents decomposition. It is usually employed in a 10 per cent. emulsion, as it is insoluble in water. Iodoform gauze is used extensively in tuberculous affections. The agent in these cases seems to exercise nearly a specific action. Iodoform powder is rapidly absorbed by the skin, and fatal cases of iodoform poisoning have occurred from treating burns with it. Iodoform is used also in ointment form and in suppositories. The symptoms of iodoform poisoning are delirium, the odor of iodoform on the breath, the presence of iodoform in the urine, an eruption over the skin, and, finally, coma. The agent is also capable of producing a localized dermatitis, with great irritation, and must, therefore, be used with care on all delicate skins. Numerous substitutes for iodoform have been brought forth at different times and by different manufacturing chemists. *Aristol* was one of the first, while *nosophen, airol, and iodol* are among the more recent substitutes. The great advantage claimed for all these is that they do not possess the unpleasant odor which is so characteristic of iodoform.

Potassium permanganate is not only an antiseptic, but a very excellent deodorizer. A 5 per cent. solution is used for sterilizing the hands, the stain being removed later by the use of a saturated solution of oxalic acid. This method of sterilizing the hands has been very extensively employed.

Alcohol possesses marked antiseptic qualities, and is one of the

best agents for the sterilization of the hands of the surgeon and skin of the patient. A 60 per cent. or 75 per cent. dilution of alcohol is more efficacious as a skin disinfectant than the 95 per cent. alcohol. This is because the purer alcohol is much less penetrating than the dilute. It is also used when diluted with water, one part to four, as a dressing for granulating wounds. It is employed to limit the action of carbolic acid when this agent has been applied in full strength. It is a useful agent in which to store certain material, such as ligatures, sutures, etc.

Silver possesses undoubted antiseptic properties, as has been shown by Halsted and others. Halsted covers his wounds with a silver-foil, and states that silver sutures do not produce infection because of their antiseptic power. Silver solutions of varying strengths are decidedly antiseptic. Solutions of nitrate of silver are used in strengths varying from 5 grains to 60 grains to the ounce. The solid nitrate of silver stick is used for destroying exuberant granulations. Innumerable silver preparations have been put upon the market as being superior to the ordinary nitrate of silver, which is generally used. The most extensively employed preparations are those known as *protargol* and *argyrol*, both of which have gained a reputation in the treatment of inflammations of the mucous membranes, especially those of gonococcal origin. The *unguentum Credé* is an ointment of silver which is used in cases of septic infection, and also in localized inflammations. From 15 to 45 grains of silver can in this way be rubbed into the skin. It is absorbed, and undoubtedly exercises an antiseptic influence on the infecting micro-organisms.

Saline Solution.—Saline solution, or normal or isotonic salt solution, as it is called, because of its close approximation to the blood-serum, consists of a solution of 0.7 per cent. of sodium chlorid in plain sterile water. Roughly speaking, and for ordinary purposes, this solution can be made by adding an even teaspoonful of ordinary table salt to one pint of boiled water, and then reboiling. It can be stored for a limited time in sterile glass jars, which are sealed with sterile cotton. The jars can be heated to whatever temperature is required for use. This solution is the one which is generally used for irrigating wounds and cavities; it is non-irritating, and possesses no antiseptic quality. It is also injected into the rectum, subcutaneously, and into a vein in cases of hemorrhage and shock. When a moist dressing is desired, there is no solution comparable to this, largely because of its non-irritating quality. It makes an excellent dressing for a burn. It has a slightly irritating effect on the kidneys, and when large quantities of it are used, it is better to dilute it.

The action of **pure oxygen** on wounds and infections has been carefully studied by Burkhardt.[9] Both pure oxygen and *ozone* have been used: apparently ozone is the more effectual. It is found that oxygen but slightly retards the growth of bacteria, but both oxygen and ozone produce a hyperemia and retard especially the growth of aërobic organisms. Pure oxygen in the abdominal cavity produces a marked hyperemia and a leukocytosis. Ozone has had some practical use in this

country, but the results have not been sufficiently studied to warrant us in recommending it.

Sunlight has a marked retarding effect on some bacteria, and actually destroys others. The anthrax spore is said to be killed very promptly by exposure to strong sunlight, and the tubercle bacillus to be slowly destroyed by it. Considered from a clinical point of view, there is no doubt that sunlight is of great help in the treatment of tuberculous lesions. *Electricity* and the *x-rays* also produce a marked retarding effect on the propagation of certain micro-organisms.

Peroxid of hydrogen is an agent of great value in the treatment of suppurating foci. It has not any marked germicidal power, but the excessive amount of oxygen which it contains is held so loosely that it

FIG. 188.—MODE OF ADMINISTERING SALT SOLUTION SUBCUTANEOUSLY UNDER EACH BREAST. (Eisendrath.)

is rapidly given up in the presence of any substance which is readily oxidized, such as pus and blood. For this reason it is very useful in cleansing infected and foul wounds, and hastening the separation of necrotic tissue. It has also a marked hemostatic power, and is used to some extent on this account in nose and throat work. Its hemostatic power is observed also in bone cavities. Care should be taken never to use this agent unless there is a free exit, as it increases rapidly in volume after coming in contact with dead tissue or pus, and serious accidents have happened from its improper use; for instance, if it is injected into an abdominal sinus where free escape is not provided for, the increase in volume will result in rupture of the sinus and infiltration of surrounding tissues, possibly of the peritoneal cavity. The distention produced

by it is also quite painful, and therefore only a small quantity, or a much diluted solution, should be introduced into cavities.

Plain sterile water is a fluid which should always be provided in large quantities for any operation, for the purpose of cleansing the wound and washing the instruments and surgeon's hands during the progress of the operation, etc. Both plain boiled water and salt solution are much preferable to any of the antiseptic solutions for these purposes.

MATERIALS EMPLOYED.

Use of Sutures and Ligatures.—Catgut is the material which is most generally employed for sutures and ligatures. It is made from the submucous coat of the intestine of the sheep. Its great advantage is the fact that it is absorbed by the tissues; its greatest disadvantage has been the difficulty of sterilization; this, however, has been entirely overcome in the past few years. Another objection that is advanced against catgut is that when it becomes moistened with the secretions of the wound, it is apt to come untied. This objection, however, does

00 0 1 2 3 4 5 6

FIG. 189.—SURGICAL CATGUT, SCALE OF SIZES.

not hold where three properly applied knots are tied and the ends of the ligature are not cut too short. Where there is tension on the suture, or when the ligature constricts large blood-vessels or a thick pedicle, the ends of the suture should be left from $\frac{1}{4}$ to $\frac{1}{2}$ inch long. Where there is a tendency to slipping of the first knot, the second knot should be a granny-knot, and the third a reef or flat knot. If the second knot is a granny, the first knot can be made much tighter when the granny is applied.

Until recently many surgeons declined to use catgut because of the unreliability of its sterilization. At present, however, there are a number of methods that can be absolutely relied upon. Catgut is obtained in sizes from 00 up to 5 and 6, which latter are but seldom employed, but which may be used for the ligation of large pedicles and large blood-vessels. When catgut is obtained in the raw state, it should go through a certain preliminary process of preparation, irrespective of the special form of sterilization to be later performed. It should

be cut into the required lengths and placed on glass reels or in coils, and should be soaked in ether for twenty-four hours to take the grease out of it. The gut put upon the market by firms of recognized reliability can, as a rule, be trusted for its sterility; much of this gut, however, is brittle, either from bad selection of the original gut or from oversterilization. Gut can be made to remain unabsorbed for a longer period by being chromicized. This is accomplished by soaking the sterile gut in a 4 per cent. solution of chromic acid for twenty-four hours. Gut treated in this way will remain unabsorbed for from ten to twenty days, according to the size of the gut, the strength of the chromic solution, and the time it is in the solution. During recent years iodized gut has become very popular, and probably those forms of sterilization which include the use of iodin are more satisfactory than any others. Iodized gut is nearly as slowly absorbed as is chromicized gut. One of the objections to the iodized gut is that it is frequently brittle.

The simplest method of iodin sterilization is that of Claudius. It consists in placing the gut for eight days in a solution of iodin and potassium iodid, 1 per cent. of each. Burmeister's[10] modification of the Claudius method is as follows: The use of a mixture of 1 Gm. metallic iodin in 15 Cc. or 22.5 Gm. of chloroform, instead of the ordinary solutions of iodin. The catgut is placed in this mixture for a week, when it is ready for use. The chloroform evaporates so rapidly that the catgut dries in a minute, but always retains its flexibility. Burmeister claims that catgut thus prepared never becomes friable, never swells when placed in aqueous solutions or living tissues, can be kept dry or in a fluid, as desired, never has any irritating action, whether rinsed or not, while it is fully as strong as, if not stronger than, that prepared by other technics.

Moynihan's[11] modification of the Claudius method is as follows: In 10 ounces of sterile water dissolve 1 ounce of crystals of potassium iodid. When all the crystals are dissolved, 10 ounces of sterile water are added and then 1 ounce of iodin crystals. The whole is then diluted with 4 pints of sterile water. The result is a 1 per cent. solution of iodin and potassium iodid. Unless the solution is made in this way, he finds that the crystals of iodin do not completely dissolve and the solution is, therefore, weaker than it ought to be. He keeps the catgut for eight days at least in this solution before using, and finds that it keeps well in the solution for at least six months.

Bartlett's[12] method of sterilization is as follows: The string of catgut coils is dried for one hour at a temperature of 180° F., and then for a second hour at 220° F., the change in temperature being gradually accomplished. The catgut is placed in liquid albolene, where it is allowed to remain until perfectly "clean," in the sense that the term is used in the preparation of histologic specimens. This is usually accomplished in a few hours, though it has been Bartlett's custom to allow the gut to remain in the oil over night. The vessel containing the oil is placed upon a sand-bath, and the temperature raised during one hour to 320° F., which temperature is maintained for a second hour.

By seizing the thread with sterile forceps the catgut is lifted out of the oil and placed in a mixture of iodin crystals one part and Columbian spirits (deodorized methyl-alcohol) 100 parts. In this fluid it is stored permanently, and is ready for use in twenty-four hours; the thread is then cut and withdrawn. The Mayo brothers use this gut and highly commend it.

Recently this method has been modified at the Pennsylvania Hospital by Dr. W. E. Lee, and the following is the method now employed in that institution, the gut thus prepared giving excellent results. "Strands of plain catgut of suitable lengths (20 inches) are coiled about three fingers, and the coils strung upon a single strand of gut. These strings of coiled gut are then placed in a large glass beaker (500 c.c.), in which they remain throughout the entire process. For heating the gut an ordinary hot-air oven, such as is used in the laboratory, is employed, and within this the beaker containing the catgut is placed. The temperature within the oven is then gradually raised during fifteen minutes to 100° C., where it is maintained for another fifteen minutes (dry heat). Liquid albolene or any bland oil is then poured into the beaker, completely submerging the gut, when the temperature within the oven is gradually raised during fifteen minutes to 140° C., and kept there for the same length of time, when the flame is turned off (moist heat). The gut is allowed to remain cooling in the oil for the next twelve hours, when it is again heated to 140° C. in the same way, fifteen minutes to, and fifteen minutes at, 140° C. After cooling during the next three hours it is placed in wide-mouthed jars containing $\frac{1}{8}$ of 1 per cent. alcoholic solution of iodin, and stored away. The gut is ready for use after remaining twelve hours in the iodin solution."

The foregoing we believe to be the most satisfactory methods of sterilizing catgut. Other methods are the simple boiling in alcohol, boiling in cumol, the formalin method of Hoffmeister, and the bichlorid method of von Bergmann modified by Johnson of the Jefferson Hospital. The Hoffmeister method consists in allowing the gut to soak for from one and one-half hours to four hours, according to the size of the gut, in a 3 per cent. solution of formalin. This gut becomes very hard, and can be boiled without damage before being used. By increasing the strength of the formalin solution to 5 per cent., the duration of the gut in the tissues can be greatly increased. Johnson's modification of the von Bergmann method consists in soaking the gut in a solution of bichloride of mercury. Twenty grains of bichlorid and 100 grains of tartaric acid are added to 6 ounces of alcohol. The small sized gut is kept in this for from ten to fifteen minutes, the larger sizes from twenty to thirty minutes. The gut is then stored in alcohol, to which is added one drop of chlorid of palladium to each ounce of alcohol. Solutions of the various silver salts have also been employed for the sterilization of catgut. MacClure,[13] following the method of Crédé, soaks the gut for ten days in a 10 per cent. solution of argyrol, during which time the jars containing the gut are frequently agitated and

protected from light. At the expiration of ten days the gut is stored in alcohol. James E. Blake,[14] of Brooklyn, has conducted a series of experiments in order to study the method of Crédé on the sterilization of catgut by means of silver salts. These experiments tend to show the reliability of catgut sterilized in this way, and his conclusions are borne out clinically by Pilcher. C. Stich[15] advocates sterilization with silver nitrate, which he has used for three years with perfect satisfaction. The catgut is placed from fifteen to thirty minutes in a 1 per cent. alcohol-ammoniacal solution of silver nitrate and protected against light. The gut is then washed in alcohol and exposed to sunlight in a sterile cylinder. It is finally stored in a 10 per cent. solution of glycerin in alcohol.

Kangaroo Tendon.—Kangaroo tendon is a strong ligature material which can be sterilized in the same way as catgut. It is questionable, however, whether it has any advantages over chromicized catgut. It has been very extensively used by Coley and others in operations for hernia and also in suturing bone. It is not absorbed so quickly as catgut, and can be made to remain unabsorbed longer by chromicizing it.

Silk is the oldest and has been the most extensively employed of all suture and ligature materials. Although in recent years it has been altogether given up by many surgeons, there are others who still consider it the safest and best material. Among its advantages are the ease with which it can be procured and carried about, the readiness with which it can be sterilized by boiling, and the fact that it does not swell or irritate the tissues when left in a wound. Another marked advantage is that the knot of a silk ligature seldom slips. It may be bought in the form of twisted or braided silk. Many operators, especially ophthalmolgists, prefer to use black silk, as the sutures are more readily seen and more easily removed. Before being used it should be boiled in a 1 per cent. carbonate of soda solution. One great objection to silk is the fact that it is not absorbed, and this, to my mind, is a very serious objection, and, excepting on rare occasions in intestinal work, I never use it. In infected wounds or wounds where infection may be expected and drainage is employed, silk is distinctly contraindicated, as it is very apt to keep the sinus open for months and years, until finally the ligature is discharged or removed. Where it gives rise to no trouble it becomes encapsulated in the tissues. In intestinal work the use of silk has been largely superseded by that of celluloid thread.

Celluloid thread, also known as Pagenstecher thread, is made by impregnating linen thread with celluloid. It is very flexible, does not become tangled so easily as silk, and is especially useful as the outer, or "serous," suture in intestinal anastomoses. It can be sterilized by boiling in a 1 per cent. carbonate of soda solution.

Silkworm-gut is made from the silk-producing glands of the silkworm, which is killed just when it is ready to spin. Silkworm-gut is probably the best suture material we have for closing the external wound; it is non-absorbable, is very easily sterilized by boiling, is non-irritating to the tissues, and its stiffness may be overcome by

soaking it in hot sterile water or salt solution. It should not be used as a buried suture.

Horsehair is still used as a suture material, especially in the approximation of the skin. It is a very good suture material for this purpose, but has not the strength of silkworm-gut. It is readily sterilized by boiling.

Silver wire is a very old suture material, but at the present time, outside of bone-work, it is not generally employed. The silver is supposed by some to possess an antiseptic quality, but this quality is outweighed by its non-absorbability. In certain bone-work it is indispensable, but care should be taken in inserting it to see that it is not too tense, else the slightest movement of the part will result in breaking the suture.

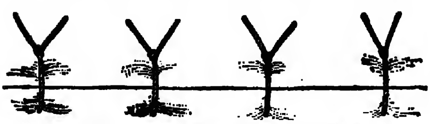

FIG. 190.—INTERRUPTED SUTURE.

FIG. 191.—CONTINUOUS SUTURE.

Aluminum bronze has recently been quite extensively employed in bone-suture, and possesses the advantage of being ultimately absorbed. This material and silver wire can be readily sterilized by boiling.

The Tying of Sutures and Ligatures.—It is undoubtedly true that much of the suppuration which formerly followed operations was the result of too tight constriction of tissues by ligatures and sutures, and this fault can be primarily traced to the inclusion of too much tissue in a ligature or suture. The tendency of the present day is not to ligate large masses of tissue, but rather to put on a number of ligatures, or to tie only the bleeding points. The old "through-and-through" suture passed through all the coats of the abdominal wall in order to approximate the deeper structures had to be tied so tightly that they constricted too much the skin and superficial tissues. This resulted in cutting and pressure necrosis. The absence of stitch abscesses in present-day surgery is not entirely due to greater aseptic care, but is largely due to the approximation of deeper tissues in their several anatomic planes or

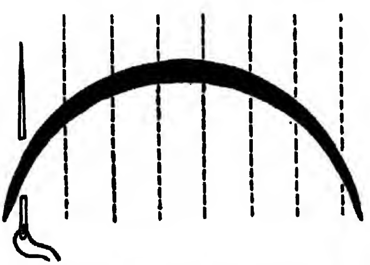

FIG. 192.—INCORRECT WAY TO SUTURE A CURVED INCISION. (Van Schaick.)

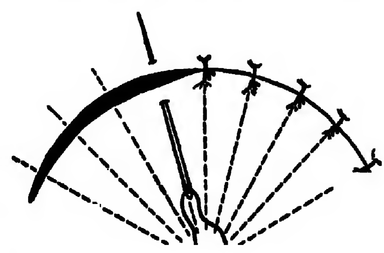

FIG. 193.—CORRECT WAY TO SUTURE A CURVED INCISION. (Van Schaick.)

layers with absorbable sutures, and the gentle approximation of superficial tissues. The skin forms no part of the strength of a wound, such as that in the abdominal wall, and consequently a gentle approximation is all that is necessary; when this is exceeded, the resistance of the

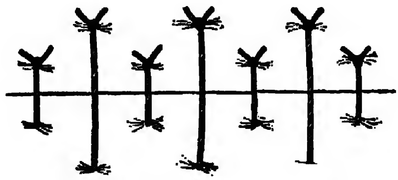

FIG. 194.—RELAXATION SUTURE.

tissues to infection is very much lessened through interference with the blood-supply.

The best knot to employ in the ligation of tissue and in the insertion of sutures is the ordinary reef or flat knot. Care should be taken, especially in the use of catgut, to see that the first knot has not slipped before

FIG. 195.—SHOWING DIRECTION OF SUTURES IN WOUND COMBINING STRAIGHT LINES, ANGLES, AND A CURVED LINE. (After Van Schaick.)

the second knot is tied. Figs. 196 and 198 show the various methods of knotting ligatures and sutures. Care should be taken to approximate the edges evenly. This can be done only by seeing that the needle emerges from one edge of the wound and enters the other at the same distance from the surface. The direction in which the suture is placed will also affect the closure, as is well shown in Fig. 195.

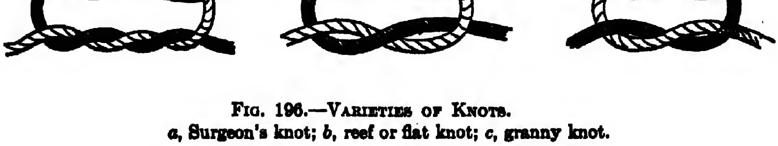

FIG. 196.—VARIETIES OF KNOTS.
a, Surgeon's knot; *b*, reef or flat knot; *c*, granny knot.

The use of the *subcuticular suture* is due to Halsted, who introduced this method of skin approximation with the idea of avoiding contact of the thread with the superficial layers of the skin, in which the Staphylococcus epidermidis albus had been shown by Welsh to be so constantly found. At the present time, however, it has been pretty clearly shown that the

greatest benefit of this method of closing the wound lies in the cosmetic result, and for this reason it should be thoroughly understood and employed wherever the least possible scar is desired, as, for instance, on the face and neck. Whenever a subcuticular stitch is employed for closing the skin, a subcutaneous suture of catgut should be introduced,

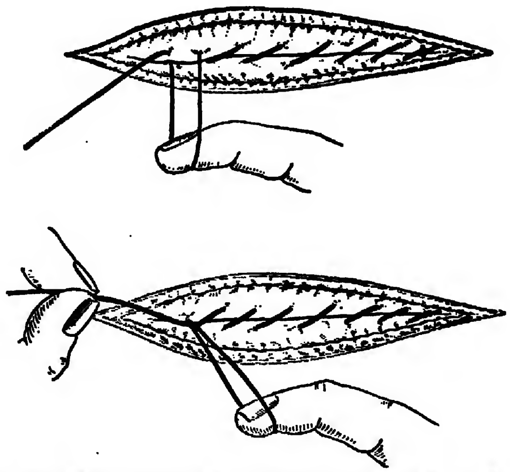

FIG. 197.—METHOD OF TYING A CONTINUOUS SUTURE. (Veau.)

which neatly approximates the superficial fascia. If this subcutaneous suture is not introduced, there will ultimately be considerable spreading of the scar. Wherever possible, this method of wound closure should be employed on exposed parts. The method of introducing the suture is shown in Fig. 383, p. 718, Vol. III. Either catgut, silkworm-gut, or silver wire may be used.

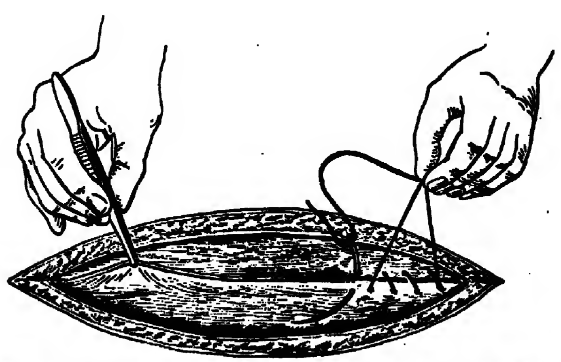

FIG. 198.—METHOD OF APPROXIMATING FASCIA WITH CONTINUOUS SUTURE. (Brickner.)

After a silkworm-gut or silver wire subcuticular suture has been introduced, it should be moved back and forth several times through the tissues so as to render its subsequent removal easy. Sometimes there are twists or kinks in it which render the removal difficult, and these should be straightened out at the time of introduction.

Needles vary greatly in size and shape. A needle should always make a sufficient opening in the tissues to allow the suture material to follow it easily. In delicate structures, like the mucous membrane and peritoneum, a round needle does much less damage to the tissue and there is less likelihood of tearing when the suture is tied than when needles with cutting-edges are used. The Hagedorn needle requires a particular forceps for its use, and has the objection of making a much larger opening in the tissue than is necessary for the passage of the suture. Richter's needle forceps is one of the best for universal use. The forceps which I nearly invariably use is a device of Dr. F. O. Allen. It consists of a small hemostatic forceps, the serrations of one blade having been obliterated. This makes a short forceps, which, we think, gives a much better control of the needle than does the longer variety. Needle-forceps are innumerable in variety, and each surgeon has his individual preference.

FIG. 199.—RICHTER'S NEEDLE-HOLDER. (Fowler.)

Removal of Sutures.—When a suture has served its purpose, that of approximating the tissues until union occurs, it should be promptly removed. It is often necessary to remove stitches before healing occurs, because of tension or infection. Most of the infections that occur are superficial, and when the skin stitches are removed and the wound properly dressed, infection is overcome and the wound heals by granulation without any disturbance of its deeper layers. One of the great advantages, therefore, of introducing the sutures in layers is that, in case infection does occur, the superficial stitches can be removed without interfering with the strength of the wound closure. In an ordinary wound the stitches are removed anywhere from the fifth to the tenth day. The removal of sutures to the lay mind is always supposed to be a painful operation. This is the result of experiences during the preantiseptic period, when silk and silver wire were extensively employed, and when inflammation in the wounds and stitch abscesses were common. There is no reason why the removal of properly applied sutures should be painful. Fig. 200 shows the method of removing a suture. It should be slightly drawn up out of the tissues and cut close to the skin, in order to avoid the dragging of the dry portion of the suture through the tissues, and the suture, if it is of silkworm-gut, should then be withdrawn in the same direction it occupies in the wound. If it is

drawn out at a different angle, it is apt to give rise to some pain. As a rule, the stitch should be grasped at right angles and rolled out by a circular motion. The reinsertion of sutures occasionally is necessary for the closure of a granulating wound. These can usually be introduced with but little pain if a sharp needle is used, and one which is larger than the suture material, or the skin along the suture line may be infiltrated with Schleich's fluid. The removal of a non-absorbable subcuticular suture (Fig. 201) is accomplished by first withdrawing one end a short distance and cutting it off close to the wound; the other end of the suture is then grasped firmly with a hemostatic forceps and quickly withdrawn, the wound being supported by pressure with the hand. The forceps grasping the suture should not be turned at right angles to it or it will cut the suture.

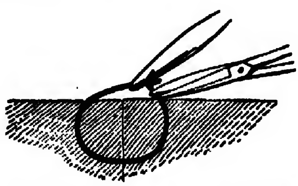

FIG. 200.—REMOVAL OF A SUTURE.

FIG. 201.—REMOVAL OF A SUBCUTICULAR SUTURE.

Dressings.—The dressing most extensively used in surgery to-day is made from ordinary cheese-cloth. This cheese-cloth, or gauze, should be boiled in a 1 per cent. solution of carbonate of soda to remove the sizing and increase its power of absorption. The gauze, which is put up by the various surgical manufacturing companies, however, has already been put through this process. Before operation the gauze should be cut and folded into various shapes, to be used both for sponges and dressings. Care should be taken that the frayed edge of the gauze, after the selvage is cut off, be folded into the center of the dressing, so that there is no chance for loose threads of the gauze to be left in the wound. Having prepared a proper number of pads for dressings and sponges, a certain number, carefully counted, should be wrapped securely in towels or pieces of muslin and sterilized in an autoclave under pressure. In a private house this gauze can be boiled or baked in an oven. The plain sterile gauze put up by the various reliable manufacturing chemists can generally be relied upon for subsequent dressings, but for use during the operation and for the primary dressing it should be resterilized. For sponges and for drains this gauze should invariably be resterilized. Medicated dressings, such as boric-acid gauze, bichlorid gauze, etc., possess little or no bactericidal power, and cannot be relied upon. One form of medicated gauze which is an exception to this rule is the iodoform gauze. Iodoform is only mildly bactericidal, and certain organisms can live in its presence; therefore, when iodoform gauze is used, it should be made from iodoform which has been sterilized, or it should be sterilized after it is made. It may be made as follows: Four ounces each, by weight, of iodoform, glycerin, and alcohol and 5 grains of corrosive sublimate are well mixed and allowed to stand for

three days. Moist sterile gauze is then saturated with the emulsion, allowed to drip until almost dry, and is then kept in sterilized covered glass jars. Another satisfactory method is to place the gauze in the following mixture: Iodoform, 1 pound; glycerin, 1 pint; boiling water, 2 pints; Castile soap, enough to saponify. The iodoform is first sterilized under five pounds pressure for half an hour. The other ingredients are sterilized by boiling.

Cotton is indispensable in surgery, and can be easily sterilized by dry heat under pressure.

Many other materials have been and still are being used for dressing in cases where there is marked suppuration or the discharge from wounds is excessive. Moss, oakum, and excelsior are materials which can be used for this purpose and can be readily sterilized. It is so seldom necessary to use large dressings and to change them frequently that there is little use for these materials, but where they are called for, they will be found satisfactory.

Sponges.—Sea sponges were formerly used extensively in surgery, but at present they are never used. Sponges should be made of gauze folded into square pads or made into balls, with the selvage turned into the center. Long sponges for walling off portions of the abdominal cavity can be made in various sizes and lengths. Each should have attached to it a 6- or 8-inch tape which can protrude from the wound and be caught with a hemostatic forceps.

Some surgeons prefer the use of large square gauze pads with a tape attached to one corner. Personally, I have found the long, narrow gauze packs to be more serviceable, as they can be passed through a smaller wound and more easily removed. One of the great dangers of using sponges in the abdominal cavity is the possibility of neglecting to remove them. In the ordinary abdominal operation there is little danger, but in extensive operations, where there is bleeding or where there is a quantity of pus, as in an extensive peritonitis, it becomes an easy matter to overlook a gauze sponge. The most careful count should be kept by the nurse of the number of sponges of each kind employed in the operation, and these should all be accounted for before the wound is closed. In addition to this the surgeon and his assistants should watch carefully the disposition of each sponge placed in the abdomen. My own rule is never to leave in the abdomen for a moment a sponge that has not attached to it a tape which protrudes from the wound and to which is applied a hemostatic forceps. It is only by developing a careful technic and a thorough organization of assistants that these accidents can be avoided. The same careful count of instruments, especially of the hemostats, should be kept.

Drains and Protectives.—Glass drainage-tubes are not so extensively used as formerly, but occasionally are indicated in abdominal work. They can be easily sterilized by boiling. Great care should be employed in the placing of these glass drains, as by pressure they may possibly produce ulceration and necrosis. It is but seldom that a glass drainage-tube is indicated. Rubber drainage-tubes are still used

very extensively, though gauze drains have taken their place to a great extent. The rubber drainage-tubes can be sterilized by boiling just prior to operation. A combination of gauze and rubber drainage can be employed, the tube being split from end to end in a spiral manner, and the gauze placed inside it. Another form of drainage very much like this is made by folding the gauze into the required size and surrounding it, excepting at the two extremities, with gutta-percha tissue. Smaller drains of this kind are also referred to as cigarette drains. Von Mikulicz used a bag of gauze in which were placed strips of iodoform or other gauze, to which a thread or tape was attached to facilitate their subsequent removal. Gauze, where applicable, is undoubtedly the best drain which we have, as it readily drinks up any secretion, and liberates it through capillary attraction. Many surgeons, notably Moynihan and Murphy, prefer rubber tubes to the gauze drains. Occasionally, as, for instance, in operations for empyema, a rubber

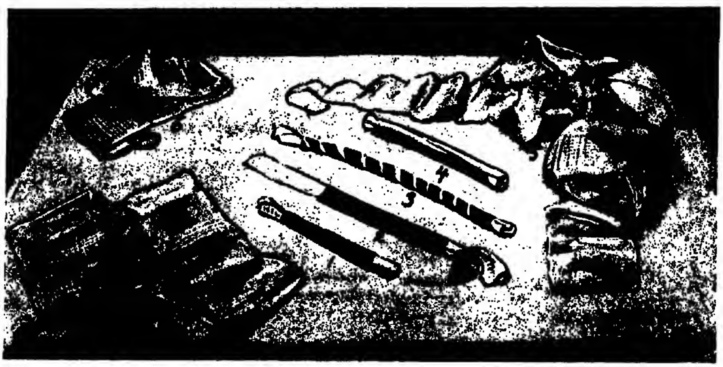

FIG. 202.—1 and 2, Gauze rolled loosely in rubber tissue ("cigarette" drains); 3, rubber tube in spiral shape and surrounding strips of gauze; 4, split rubber-tube drain; 5, 6, 7, 8, gauze packs and drains of different widths and lengths.

drainage-tube is indispensable. Where we use a rubber drain a large-caliber tube should be employed, otherwise it becomes blocked with blood-clot or thick pus and does not perform its function. Where a rubber or glass drainage-tube stays in the wound for any length of time, it should be occasionally moved, so as to prevent the openings in it from becoming blocked with granulation tissue.

It is important in using rubber or glass drainage-tubes to see that there is no possibility of the tube slipping entirely in or out of the wound. Most of the glass tubes are flanged at the top, which prevents their slipping into the wound, and the dressing prevents their slipping out. With rubber tubes a safety-pin should be passed through them or they should be sutured to the edge of the wound. Neglect of this precaution sometimes produces very troublesome complications. I have seen a long rubber drainage-tube removed from a chest cavity nine months after operation for empyema. The tube disappeared, and it was supposed that it had slipped out of the wound and been lost, while,

as a matter of fact, it had been improperly secured and had slipped into the pleural cavity and there remained until removed at a subsequent operation. One of the chief objections to gauze drainage is the pain which accompanies its removal. In taking out a gauze drain it should first be carefully separated from the edges of the wound, as at this point it is most adherent. It should also be thoroughly saturated with warm salt solution. Where difficulty and force are anticipated in the removal of a gauze drain or pack, it is far better to remove it gradually after thoroughly saturating it with salt solution, taking several days for the removal, or else to give the patient an anesthetic. We have used chloride of ethyl anesthesia for this purpose with the greatest satisfaction. The patient is quickly anesthetized, and recovers consciousness within a few minutes after the removal of the gauze. Where another gauze drain is to take the place of the one which is removed, it should be prepared and ready for insertion *before* the original drain is removed; if this rule is not followed, the operator will sometimes have difficulty in inserting the new drain, as the tissues quickly contract, especially in the case of a recent wound.

The sterilization of *rubber tissue* or *gutta-percha tissue*, *rubber dam*, and *oiled silk* is accomplished by soaking them in a bichlorid solution (1:1000) for thirty minutes. *Cargile membrane*, which is made from the peritoneum of the ox, and sometimes employed to prevent adhesions, is supplied by the manufacturer in an aseptic condition. Silver-foil can be sterilized with dry heat.

Bandages.—The bandages employed in surgery at the present time are either made of muslin or gauze. The gauze bandages are put up and sold by the various manufacturers, each bandage being wrapped in thin paper. Such bandages are the best for applying dressings to the head and for wounds. On the trunk, however, and in fracture dressings, the gauze bandage has no place. On the trunk, they are apt to become rolled up into cords, which are uncomfortable to the patient, and in the dressing of fractures they are too soft to give much support and do not exert an even pressure. Muslin bandages have been used for all time in surgery. These can be easily made by cutting the unbleached muslin in strips of varying widths—from six to eight yards in length. The selvage should be cut off and the frayed edges removed; the bandage can then be rolled on an ordinary bandage-roller. These bandages are also manufactured and are perfectly satisfactory.

Plaster-of-Paris Bandages.—These are made by impregnating starch-stiffened crinolin gauze of large mesh with plaster-of-Paris. Care should be taken to see that the gauze is stiffened with starch, and not with dextrin or glue, as the latter retards the setting of the plaster. The crinolin gauze is cut in strips of varying widths from two to four inches and four yards long; these are then rolled loosely over a smooth surface, the plaster being rubbed into the meshes as the bandage is rolled. The bandage having been thoroughly impregnated with the plaster, it is handled as little as possible. It may be rolled in tissue-paper and should be kept in a dry place. When needed for use, the

bandage is placed standing on end in a basin containing enough water to cover the entire bandage, and it should remain in the water until the air in it has escaped, as can be told by the cessation of bubbles. It is then squeezed firmly in the hand and is ready for application. The part to which a plaster bandage is to be applied should be protected by either a flannel or a lint bandage, or by flannel or cotton undergarments. Cotton padding should be used to protect the bony prominences from pressure. When applied to the trunk, allowance should be made for respiration and the changes in the size of the abdomen; this can be done by placing a folded towel underneath the bandage or shirt, it being withdrawn after the plaster has been applied. Where swelling of the part is to be expected, as in a compound fracture or in operations upon the bones of the extremities, I have found it a good plan to cut the plaster dressing just before it sets. The part should be held in the desired position until the plaster has completely set. It is unnecessary to rub into the plaster dressing large quantities of thick cream made from the plaster; it adds to the neat appearance of the dressing, it is true, but it also adds to its weight.

Fig. 203.—Pelvic Support During Application of Spica of Hips.

The removal of a plaster dressing is often a troublesome procedure, but can be greatly facilitated by cutting the plaster before it sets, as already suggested. There are a number of plaster-cutters on the market which greatly facilitate the removal of this dressing. Where these are not to be had, a sharp, thick-bladed knife is of greatest advantage. At the time the plaster is applied a rope or a triangular rubber strip may be placed under the plaster, along the line where it is to be cut; the rope or rubber is removed after the dressing has set, and the blade of a scissors can easily be passed into the space thus made. A good way to facilitate the removal of a cast is to place under the cast, where the line of incision will be made, a strip of lead or zinc about ¾ inch wide. The plaster can then be cut, and the lead or zinc strip protects the patient. The strip, if previously anointed with vaselin, can be readily withdrawn without any disturbance of the cast. Bechtol[16] removes his casts by cutting them with Gigli saws; in the leg, for instance, a saw is applied all the way down the front, another down the back as far as the heel, and a third along the sole of the foot. When the plaster is dry, it is cut through its entire length, anteriorly, posteriorly, and along the sole of the foot, with the saws. This makes two lateral splints of the cast.

Silicate of soda makes a very good firm dressing, especially useful in fractures, but has several disadvantages. In the first place, it is heavy, unless a very thin dressing is applied, and in the second place, it takes a long time for hardening or setting, which is a great disadvantage in treating recent fractures. In the later stages of the fracture,

after the fragments have become more or less fixed, it is a very useful and convenient dressing. Silicate of soda can be bought in thick solution, which requires dilution with water in order that it may be taken up by the bandages. The dressing may be applied in two ways: first, ordinary muslin bandages are soaked in the solution for a number of hours, preferably twelve, until they have become thoroughly saturated; they are then applied just as the plaster-of-Paris bandage is applied, and with the same precautions as to pressure. The part should be kept perfectly quiet until the dressing has completely set. On damp days the setting may not be complete in twenty-four hours. The second method of applying the dressing is that of encircling the part with the muslin bandage without saturating it in the solution, and then applying the thick solution with a brush over the bandage. Gauze bandages may also be used in this way.

Adhesive plasters have been used for a long time in surgery, but the old plasters required heating in order to develop the adhesive

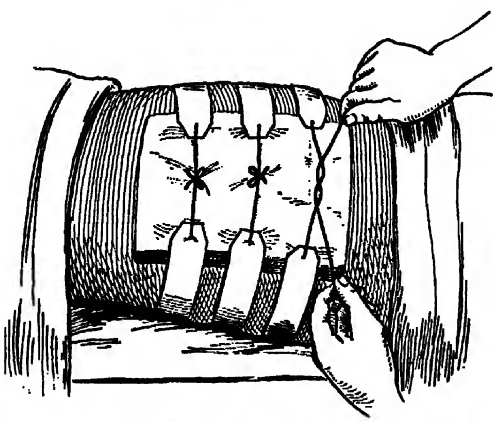

FIG. 204.—FIXATION OF DRESSING WHEN FREQUENT CHANGE IS NECESSARY.

quality. These plasters were followed by the rubber adhesive, which is used to-day. Recently, the rubber adhesive plaster has been improved by the addition of zinc oxid, which renders it much less irritating to the skin than the plain rubber plaster, and it is not more expensive. This "Z. O." adhesive plaster can be bought in wide rolls or on tin spools; the latter, excepting for hospital work, are probably the most convenient. They can be bought in widths varying from ½ inch to 3 inches, and in lengths of 5 or 10 yards. Adhesive plaster is indispensable in surgical work. It is one of the best means we have of fixing a dressing so that it does not become displaced. The strips may be applied transversely, vertically, or diagonally. When but one dressing is needed, the plaster can be applied directly across the dressing; if, however, it is desired to change the dressing frequently, then the plaster strips are attached to the sides of the abdomen, the ends folded over, perforated, and threaded with a tape; these tapes are then tied, as shown in Fig. 204. A strip of adhesive plaster 2 inches

wide across the abdomen is a great support to the wound during the postoperative period. I have found it especially advantageous in hernia operations, as it prevents the slipping up of the dressing and exposure of the wound. The strip should start between the trochanter and crest of the ilium, and pass directly across to the opposite side. In fractures the adhesive straps are very useful for keeping the splints and pads in place. In fractures of the ribs the adhesive strips alone constitute the dressing. Strips of adhesive plaster are far more satisfactory than pins for keeping a bandage in proper position on an extremity. Dr. C. L. Leonard[17] has had made an adhesive plaster which is adhesive on both sides. It can be readily seen that in some cases this is very advantageous: if the plaster is sterile, it can serve the double purpose of closing the wound and keeping the dressing in place.

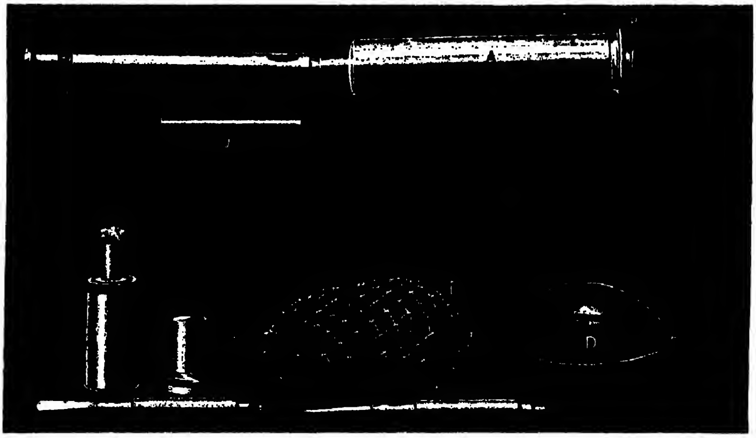

FIG. 205.—PAQUELIN'S THERMOCAUTERY. (Fowler.)

A, Hollow handle containing absorbent cotton, saturated with benzin; B, removable cap; C, connecting tubing; D, rubber bulb; E, secondary bulb guarded by netting; F, alcohol lamp and cap; G, knife-shaped cautery point; H, pointed cautery point; I, dome-shaped cautery point; J, extension attachment to be used with the shorter cautery points.

Lilienthal[18] has strongly advocated the use of sterile zinc oxid adhesive plaster in the approximation of the skin edges. The ordinary adhesive plaster cannot be sterilized after it is made, but several of the manufacturers produce a reliable sterile article. If the wound is closed with a subcutaneous suture, the skin can be approximated as closely with this plaster as with a subcuticular stitch. In removing these strips of adhesive plaster care should be taken to support the wound with one hand and to remove the plaster by drawing it from each end *toward* the line of incision.

Sand-bags are an essential in certain surgical procedures. In operations on the skull and on the bones of the extremities a firm sand-bag, about 12 inches square and 3 inches thick, is desirable. In operations on the gall-bladder a sand-bag under the spine brings the ducts within easy access. The sand-bag should be covered with a rubber cloth to keep the sand dry. If, in spite of this, the sand should become moist, it can be dried out in an oven.

Thermocautery.—The Paquelin cautery is often necessary in surgical work, especially in operations about the rectum and mouth. Many surgeons also use it to cauterize the stump of the appendix. The cautery should always be tested some time before the operation, in order to make sure that it is working properly. The tip should be heated over an alcohol or gas-flame until it becomes a dull red; then the benzin vapor should be forced through by pressure on the rubber bulb until the tip is a bright red. Care should be taken not to pump too much air into the rubber reservoir or it will burst. An occasional pressure on the bulb is all that is necessary to keep the tip at the proper temperature. If it should go out, it will be necessary to reheat it at the lamp. A dull red heat is the proper heat at which to use the cautery. Where ether is the anesthetic employed, care should be taken to keep the cautery well away from the ether vapor, and always *above* the level of the ether apparatus, as the vapor of ether is heavier than air and falls. After using the cautery it should be heated to a white heat in order to sterilize it, and then allowed to cool slowly.

Hypodermic Syringe.—A sterile hypodermic syringe should always form a part of the paraphernalia of any operation. It may be used for inducing local or regional anesthesia or for the administration of drugs. This is another instrument which should always be carefully tested before the operation to see that it is in working order, and especially that the needle is patulous and that there is no leakage. When a hypodermic syringe is used for the purpose of giving a drug, it should be inserted entirely through the skin into the subcutaneous tissues. If, on the contrary, it is used for injecting an anesthetic solution, it should simply enter the skin so that when the fluid is injected a welt is raised along the line where it is desired to make the skin incision. If a patient is conscious, he should always be informed that the needle is about to be injected, or else he is apt to make a sudden movement which will break the needle. A very good hypodermic syringe, the barrel and piston of which are entirely made of glass, can be had, and is especially useful in surgical work. There is no doubt that the profession has become entirely too lax in the use of hypodermic syringes, since occasionally very serious infections occur from a want of proper aseptic precaution. Fatalities have occurred after these infections, and if there is the remotest possibility of such, there is every reason why the most careful cleansing of the skin and of the needle should be made. Alcohol is an agent which can be used on both the skin of the patient and for sterilizing the needle, and as it is so readily obtained, there is little excuse for failing to carry out the sterilization.

Aspirators.—Various types of aspirators are employed; as a rule, the one having the simplest mechanism is the best. Fig. 206 shows an aspirating syringe which is of great advantage in removing fluids from the different body cavities, such as the gall-bladder, joints, the pleural cavity, etc. Such a syringe should always be one which can be readily sterilized, and as much care should be exercised in its use as when a complete operation is done For diagnostic purposes the

aspirating syringe is often used. The results, however, should not always be accepted as final, as occasionally the needle may have not only penetrated, but perforated, the supposed body of fluid, or the needle may have become blocked with a mass of tissue.

Infusion Apparatus.—In cases of shock, hemorrhage, and occasionally in other conditions, an infusion of salt solution or other fluid becomes necessary. This fluid may be injected subcutaneously, when the operation is spoken of as *hypodermoclysis;* or the fluid may be injected directly into a vein. When hypodermoclysis is employed, the site usually chosen for the injection is the tissue under the breast. Fig. 188 shows the apparatus in use. A needle of good caliber should be employed, and care should be taken to see that the needle is introduced entirely through the skin into the subcutaneous tissue. In making intravenous injection, one of the superficial veins at the bend of the

FIG. 206.—POTAIN'S ASPIRATING APPARATUS.

elbow, usually the median cephalic, is chosen. First, the skin overlying the vein is thoroughly cleansed, a bandage is applied about the upper arm, sufficiently tight to cause the veins to stand out prominently; the skin overlying the vein selected is then incised, and the vein thoroughly exposed. Two ligatures are placed around it, and the lower one tied. The upper one is caught with a forceps. By making traction on this suture the escape of blood can be prevented when the vein is opened. The vein is opened by pinching up a portion of its caliber in a small pair of forceps, and with the scissors or knife making a nick in it sufficiently large to admit the cannula of the aspirator. This cannula should gradually increase in size from its point up, so that it can be made to fit tightly in the opening. When this is not the case, it will be necessary to have a third ligature about the vein at the point where the opening is made and tie the cannula in position. A small,

sterile glass funnel connected with the cannula by a sterile rubber tube is all the apparatus that is absolutely necessary. Before introducing the cannula into the vein a little fluid should be allowed to pass through it so as to prevent the introduction of air into the vein. There has been a difference of opinion about the evils resulting from the passage of air into a vein. (See Air Embolism, Vol. I.) The temperature of the solution should be about 105° to 110° F. when it is poured into the funnel. It loses some of this temperature, of course, in passing through the tube. The amount of fluid poured into the funnel should be carefully estimated. When sufficient fluid has been introduced, the upper ligature should be tied and the cannula withdrawn. The wound is then closed and a sterile dressing applied.

(For the use of infusion in shock, see Surgical Physiology, Vol. I, p. 88, also Wounds and Contusions, Vol. I., p. 942.)

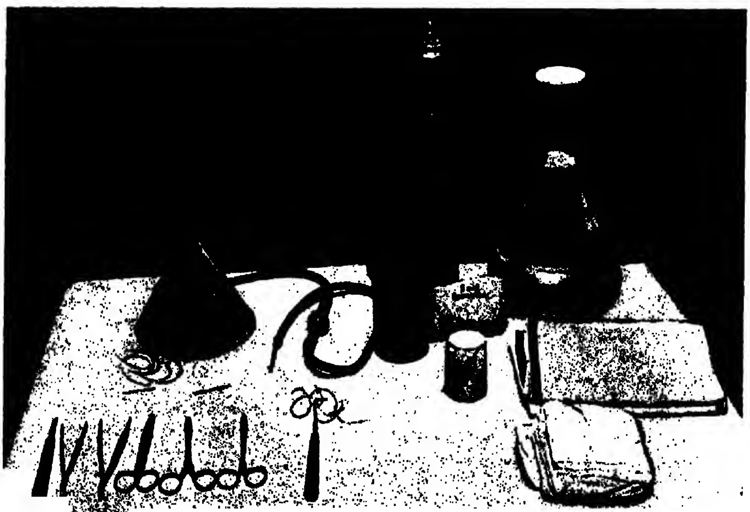

FIG. 207.—TRANSFUSION APPARATUS WITH NECESSARY INSTRUMENTS, LIGATURES, ETC.

Direct Transfusion of Blood.—Direct transfusion of blood is not a new operation, but it has been revived, owing to the recent advance in the technic of vascular surgery, largely through the work of Carrell, Crile, and others. The difficulty which has always been met with in direct transfusion is clotting of the blood, either in the vessels themselves or in the tube or cannula which intervenes between the vessel of the donor and that of the donee. Crile has devised a method, however, which brings the intima of the artery into contact with the intima of the vein, so that clotting does not take place unless the intima of the vessels has been injured by rough handling. He has shown, and many other surgeons more recently have confirmed it, that patients reduced to such a low condition by the loss of blood that any operation would be attended with grave risks may be so improved by the direct transfusion of blood from another individual that the operation may be

undertaken with impunity. The value of this method has now been demonstrated so satisfactorily from a clinical point of view by many surgeons that it must be looked upon not only as a legitimate procedure, but one possessed of great life-saving possibilities.

In Crile's recent book on "Hemorrhage and Transfusion" he gives full details of all his experimental work and reports of his own cases and those of others. He has shown conclusively by experiments that in illuminating gas poisoning transfusion will give the best results; this statement is also borne out by the cases in which excellent results have been obtained by the transfusion of defibrinated blood. He incorporates a number of cases of hemorrhage in typhoid fever in which the lives of the patients have been undoubtedly saved by direct transfusion. In jaundice also and in gastric hemorrhage, direct transfusion seems to have saved life. Carrell's case of direct transfusion in melena neonatorum is given in detail. In a private communication Carrell states that he has transfused a second baby two days old, suffering from purpura, with the same excellent result.

One of the objections to direct transfusion is the want of affinity between the bloods of certain individuals. When one blood is not adapted to the other, hemolysis is the result, with the development of a serious anemia. Excepting in the extremest emergencies the affinity of the two bloods must be determined, and this requires a number of hours. If hemolysis is found to take place when the two bloods are combined, another donor must be chosen. The disregard of this rule of determining the affinity of the two bloods may result very seriously, and, therefore, except where the donee's condition is extreme and death imminent, the examination of the bloods should not be omitted. A fatal case of hemolysis after transfusion has been reported by Pepper and Nesbitt.

Funke, who has studied this question of affinity, shows that in about one-half of the cases the bloods are incompatible. He describes in detail a test to determine the adaptability of the donor's blood.

The following is a description of Crile's technic.

"In the clinical transfusions we have utilized the radial artery of the donor and the proximal end of any superficial vein of the arm of the recipient. The radial artery was chosen because it is easily isolated and may be readily adjusted to the position of the vein of the recipient. Unless contraindicated the donor and the recipient are each given a hypodermic injection of morphin twenty minutes before the transfusion. Before they enter the operating room, after their arms are prepared, and for the purpose of minimizing the psychic factor, a nurse places over their eyes a wet towel with the diverting explanation that the eyes must be protected from the bright light to prevent headache. The donor is placed upon an operating table of the Trendelenburg type, so that should he faint the head may be readily lowered. The recipient is also placed upon an operating table with his head in the opposite direction from the donor. By the use of an infiltration anesthesia of 0.1 per cent. solution of cocain, about 3 centimeters of the radial artery are

exposed and the smaller branches tied with very fine silk; a Crile clamp is applied to the proximal end of the artery and the distal end is ligated; the artery is then divided; the adventitia is pulled over the free end as far as possible and closely snipped off; a moist saline sponge now covers this field; 3 or 4 cm. of a superficial vein of the recipient are then likewise freed; the distal part ligated, the proximal closed with a Crile clamp; the distal part is divided with scissors, the adventitia drawn out as far as possible and closely snipped off; the vessels are then inspected and a cannula whose bore is larger than the actual tissue thickness of either vein or artery is selected (Fig. 208). The vein may then be pushed through this tube, after which the freed end is turned back like a cuff and snugly tied in the second groove. During this time the handle of the cannula is steadied and manipulated by means of a forceps. If the artery is small or atheromatous and, therefore, firmly contracted or if it is contracted for any other reason, its lumen may be dilated by means of a "mosquito" hemostat pushed into the lumen and gradually opened. The artery is then drawn over the vein and is snugly tied with a small linen ligature in the first groove. This completes the anastomosis.

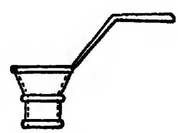

FIG. 208.—CRILE'S ANASTOMOSIS CANNULA (twice actual size).

"The clamp is then removed from the vein, afterward gradually from the artery, when the blood-stream will be seen to pass from the artery across to the vein, dilating the latter. However, the exposure and manipulation of the vessels, especially the artery, causes sharp retraction. The artery may contract so firmly as to obliterate its lumen. The constant application of warm saline solution and protection from the air will help materially in bringing about relaxation and, hence, a larger stream of blood. The pulse-wave may be palpated in the vein. It is best to introduce the blood very slowly, watching carefully the result.

"From our clinical and experimental research into the technic we have reached the following conclusions: That the vascular systems of two individuals may be united so that intima comes in contact only with intima; that this may be accomplished by the Carrell suture or by a special anastomosis tube, which is the method of choice; that blood may be transferred without clotting; that the use of the radial artery of the donor and any superficial vein of the recipient yields the best results; that the operation may be done painlessly; that the blood lost by the donor is regained in from four to five days; that the amount transferred is under the immediate control of the operator; and that the rate of transference should be carefully gauged because of the risk of overcharging the pulmonary circulation."

J. A. Hartwell, of New York, has described a simple method of blood transfusion without a cannula. His plan is simply to insert the artery into the vein after first having lubricated the artery with sterilized petrolatum. The vein is made taut around the artery by pressure forceps.

Both the method of Crile and that of Hartwell have been improved upon by Brewer, who recommends the use of glass tubes about 2½ inches long, small at one end, for insertion into the artery, and large at the other, for insertion into the vein, and lined with paraffin (Fig. 209). The length of the tube and its easy insertion into the vessels makes the operation much simpler and easy of accomplishment. I have used Brewer's tube with the greatest satisfaction in one case.

Another modification of the Crile tube has been devised by Hepburn. This would appear greatly to facilitate direct transfusion. I am inclined to think, however, that now that we have been shown that it is possible to do a transfusion with the glass tube, that this will become the method generally used. A very complete review of the manner of direct transfusion has been presented by Ottenberg, who reports a number of experiments and two clinical cases.

From the clinical cases reported it is evident that direct transfusion is not as successful where the patient is suffering from serious septicemia, pernicious anemia, and leukemia as where it is simply a case

FIG. 209.—BREWER'S GLASS TUBE LINED WITH PARAFFIN.

of the loss of blood. Even these serious conditions, however, are at least temporarily benefited, and further work may prove the results to be more permanent. In one of my own cases, where a direct transfusion was done for pernicious anemia, the improvement has been remarkable, but it seems as though the result is not going to be permanent. Apparently the good results which follow direct transfusion are not entirely due to the mere quantitative or functional re-enforcement of the blood, but to the stimulating effect of the transfused blood, especially upon the bone-marrow. Carnot has devoted considerable study to this subject and has conducted extensive experiments upon rabbits. He believes the existence of certain substances in the serum of anemic animals, which he calls hemopoietins, are supposed to stimulate the bone-marrow to increased reproduction. The balance between the hemolysins and the hemopoietins is changed in favor of the hemopoietins after severe hemorrhage. He is of the opinion that the transfusion of defibrinated blood prepared by a method which he describes will give as satisfactory results as direct transfusion.

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STUDY OF THE PATIENT.

Before undertaking any surgical procedure a careful study of the patient and a thoughtful consideration of his personal and family history are necessary. It is important that a habit be formed of taking a systematic history and making a systematic examination of the patient before operation, else one is sure to have many painful and humiliating surprises. Such histories should be filed and indexed.

Temperament, at one time, was supposed to influence largely the prognosis. With our increased knowledge of the causes of disease, infection, and death, this factor of temperament has played a less important part; nevertheless experience teaches that temperament does affect to some small degree our results. A patient of a hopeful, sanguine temperament is much more apt to aid our efforts and to recover smoothly than one who is melancholic and lethargic.

Obesity and plethora also influence the surgical prognosis. Fatty tissue necroses very rapidly, especially if it is injured or constricted, and is frequently the predisposing cause of suppuration. Fat embolism also is more apt to occur in these patients. Very stout patients take an anesthetic much better than would be expected, but rest in bed in a constrained position is very hard on them. Where there is time, it is far better to try to reduce the weight of very obese patients before operation. This is especially true in cases of hernia. In plethoric patients there is much more apt to be a congestion of the wound and a greater tendency to inflammation.

The **habits** of the patient regarding tobacco, alcohol, drugs, etc., should be carefully considered. Chronic alcoholism is a decided contraindication to any prolonged operative procedure. It renders anesthesia more dangerous, infection of the wound is more likely to occur, and the

patient may develop delirium tremens in his postoperative period. Such patients are apt to have bad kidneys, and any additional work put upon them by the anesthetic may produce serious complications. Acute alcoholism is even more dangerous. I believe that in these conditions where operation is imperative, it is a good plan to allow the patient a moderate amount of alcohol, as there seems little doubt that the complete cutting off of the supply may produce a very serious nervous condition and often delirium tremens. Drug habits, such as the taking of morphin and cocain, do much to render diagnosis difficult. The patients, and sometimes their families, will endeavor to keep the fact of such habit a secret even when a surgical operation is contemplated, whereas if it were known, it would markedly influence the treatment. Drug habitués are decidedly poor patients, and stand operative procedures badly.

Heredity and Diathesis.—These undoubtedly play a part in the prognosis, although it is very difficult to estimate their importance. Certain conditions, however, are undoubtedly hereditary, and for statistical reasons careful notes should be made regarding the family history. It is well, in studying the patient, to inquire as to whether or not there are "bleeders" in his family, for hemophilia seems to be hereditary. A predisposition to tuberculosis is certainly hereditary. The so-called lymphatic constitution is a condition which appears to be hereditary. Such patients show a marked tendency to enlargement and chronic inflammation of the lymph-nodes. The hereditary tendency to cancer has never been actually disproved, and it is well for us always to consider it. A gouty or rheumatic diathesis or tendency is usually present in patients who suffer from calculus formation, arteriosclerosis, and chronic nephritis.

Too much attention cannot be given to a study of the patient's **heart, blood-vessels,** and **circulation.** Acute valvular heart lesions are a decided contraindication to a general anesthetic. Chronic heart lesions are far less dangerous. Although patients with arteriosclerosis stand operative procedures remarkably well, there is always a danger of apoplexy from the strain put upon the vessel by the anesthetic. Sudden deaths have occurred during and after operation from rupture of a thoracic aneurysm which had not been suspected before operation. In the presence of any serious lesion of the heart or blood-vessels no operation, unless absolutely necessary, should be performed under a general anesthetic. It is in these cases that infiltration anesthesia has proved to be a great boon.

Acute lesions of the **respiratory organs,** whether of the upper air-passages or of the lungs, are decided contraindications to operations under a general anesthetic. Chronic lesions of the lung and mucous membrane of the bronchial tubes may also be greatly aggravated by the administration of a general anesthetic. *Old tuberculous lesions* may be relighted under the stimulation of a general anesthetic. No operation should be performed in the presence of an acute lesion of the respiratory tract, excepting when imperative. Carelessness in this

regard is sure to result in postoperative pneumonia in a certain proportion of cases. Failure to examine the chest carefully in cases of apparent acute abdominal crises has resulted in the performance of an abdominal operation when the symptoms were due to a beginning pneumonia or a diaphragmatic pleurisy.

Inflammatory diseases of the kidney, whether acute or chronic, but especially if acute, decidedly influence the prognosis in surgical operations. The danger lies chiefly in the anesthetic, and especially in ether, which, being eliminated by the kidneys, aggravates to a marked degree the lesion. Here some means of avoiding a general anesthetic, and especially ether, should be taken. (See chapter on Local and Spinal Anesthesia.) Inquiry should be made regarding the passage of blood in the urine and regarding painful and frequent micturition. *Diabetes* has for many years been looked upon as a decided contraindication to operation, not only because of the danger from the anesthetic, but because suppuration and gangrene are so apt to occur in the wound. We have lately learned, however, that certain diabetics stand operation perfectly well. Phillips,[10] who has studied this condition very thoroughly, has laid down the following rules regarding operation:

"A thorough examination of the urine must be made in all cases. Not only the amount of sugar is to be ascertained, but the presence or absence of acetone or acid bodies; the ferric chlorid reaction and Lugol's test should be employed in every instance. The presence of oxybutyric acid is not easy to demonstrate or to estimate, save by the polarimeter. The total amount of ammonia must always be estimated. No operation save of the extremest urgency is to be performed if there is over one gram of ammonia excreted in the twenty-four hours until this has been reduced to the normal amount. An operation should be postponed if there be aceto-acetic acid in the urine, though the ammonia be not markedly increased. Much albumin in the urine is a bar to operation. If serious disease of other organs, such as the liver, be present, an operation should be avoided. Rapid wasting in a stout diabetic not obviously dependent on the surgical lesion demanding treatment should be a reason for postponing an operation until the general condition is improved. An operation should be performed: (1) For malignant disease, if, apart from diabetes, such would be urged; (2) in the case of large abdominal tumors, especially in females; (3) in diabetics in good health without extensive arterial or nerve degeneration, cosmetic operations may be performed, especially in females; and (4) an emergency operation is to be undertaken even in the most unfavorable circumstances, but a very guarded prognosis is to be given. Save in the last category, if any of the indications against operation be present, the operation should be postponed until they are ameliorated." I have followed these rules for a number of years and have been able to operate on many diabetics successfully, whereas formerly I would have declined to operate.

Syphilis, either hereditary or acquired, is capable of greatly inter-

fering with good postoperative results. If, however, we take the precaution to give the patient proper antisyphilitic treatment for some time before and after operation, the results will be perfectly satisfactory. Operations, excepting those of emergency, are not to be undertaken in the primary or secondary stage of syphilis. After operations on syphilitics it is of the greatest importance to keep up the antisyphilitic treatment. Many good operative results are ultimately spoiled by neglect of this precaution. The patient cannot be impressed too forcibly with the necessity of carrying on his treatment after an apparent cure.

The existence of an acute or subacute *gonorrhea* is a decided contraindication to operation, excepting those of absolute necessity, since infection of the wound with the gonococcus is always a possibility.

Tuberculosis.—In the absence of tuberculous lesions in the lung operations for tuberculous conditions, generally speaking, offer a fairly good prognosis. An important part of the treatment of tuberculous lesions, and one which surgeons are apt often to neglect, is the hygienic and dietetic treatment of the patient before and after operation. Many recurrences requiring repeated operations result from neglect of this care. Tuberculous patients, as a rule, stand prolonged surgical procedures remarkably well. Any lesion of the lung, however, greatly increases the danger of operation, and, where it is possible, a local anesthetic of some sort should be employed in these cases.

Blood.—Examination of the blood is absolutely necessary in certain surgical conditions, and valuable information can always be obtained from such examination. It should consist in the estimation of the hemoglobin, a count of the red and white blood-cells, and a differential count of the white cells. In the presence of jaundice an estimation of the coagulation time is also necessary, since in a prolonged jaundice the coagulability of the blood is greatly reduced, and fatal hemorrhage may be the result of an operative procedure. Where jaundice is present, preparatory treatment with calcium chlorid has been recommended very strongly by Mayo Robson.[20] Thyroid extract, as pointed out by W. J. Taylor, is also an agent which tends to prevent and control hemorrhage, such as occurs in the presence of jaundice. *Anemia*, if it is at all marked, and especially if it is due to a condition which the operation will not remove or relieve, must be looked upon as a contraindication to operation. It is a condition, however, which can be greatly benefited by treatment before operation. The value of the leukocyte count, and especially the differential count, has been clearly shown in the chapter on The Examination of the Blood (Vol. I., p. 126). The estimations of the percentage of hemoglobin necessary to render an operation permissible have varied greatly, some authorities stating that an extensive operation where the hemoglobin is below 50 per cent. is extremely dangerous, and when below 40 per cent., should not be undertaken except in an emergency; others reduce these estimates to 40 per cent. and 30 per cent. As a matter of fact, no absolute rule can be laid down for the guidance of the surgeon. I have performed a successful hysterectomy for fibroids where the hemoglobin was below

30 per cent., but, of course, it was done for uterine bleeding which could not be controlled by any other means. Unless absolutely necessary, the operation should be postponed in the presence of a low hemoglobin until the condition can be improved, as it nearly always can be by treatment.

Acute Diseases.—Nothing is more important, especially in children, than the exclusion, as far as possible, of acute diseases, such as tonsillitis, measles, diphtheria, scarlet fever, typhoid fever, etc. In studying the patient, inquiry should always be made as to his recent environment, whether or not he has been in contact with contagious diseases, and whether he has had these. Often children are admitted to the hospital for operation on the day subsequent to their admission, and on this day they will develop one of the eruptive fevers or some other acute condition. It is our rule, in children especially, to have the patient admitted, not on the day before operation, but several days before, so as to avoid the possibility of an operation during the incubation period of these acute maladies. The taking of the temperature for several days previous to operation is a good plan, and often enables us to avoid operating in the beginning of some acute infection.

Nervous Diseases.—Operations in the presence of insanity have been considered at length in Volume II. In such conditions as hysteria and the various forms of neurasthenia it can be said that, as a rule, good results after surgical operations are greatly interfered with. To undertake operations for the relief of nervous disorders of this kind is very questionable, usually results in disappointment, and often in rendering the condition of the patient worse. The results of operations in the presence of spinal lesions and lesions of the peripheral nerves are in no wise interfered with, unless, of course, the field of operation lies in an area where already there are trophic changes, or where there is reason to expect these.

Alimentary Tract.—Before undertaking any surgical procedure of magnitude the condition of the alimentary tract should be carefully considered. A mouth containing decayed and unclean teeth is sure to contain organisms of the greatest virulence, and the administration of an anesthetic under these circumstances may result in a septic infection of the lung, or, in operations on the alimentary tract itself, in a serious infection at the site of the wound. The teeth, therefore, should always be placed in good condition prior to operation. Any complaint on the part of the patient of dyspepsia or indigestion should be thoroughly investigated, as an operative procedure on some other organ in the presence of an ulcer or cancer of the stomach would not be justifiable except in an emergency. A careful history as to vomiting, especially the vomiting of blood, as to the condition of the bowels, and as to the passage of bloody mucus, should be obtained. One of the most important things before any operation is the thorough emptying of the intestinal tract. When this is not done, there is sure to be a more or less severe autointoxication from the intestinal tract in a certain proportion of cases.

Thyroid.—The presence of a goiter should always make us hesitate about the performance of an operation, and if the goiter is accompanied by exophthalmos or other indications of Graves' disease, only operations of the most urgent necessity are to be undertaken, and then only after the dangers have been explained. Not only does the danger result from the mechanical interference with breathing and pressure on nerves, but persons who are the victims of thyroid tumors often suffer from severe shock for which it is difficult to account.

Deformities of the chest, especially those the result of disease, should be carefully investigated, as serious interference with respiration during the anesthesia may result from them. In such cases it may be advisable to employ a local anesthetic.

PREPARATION FOR OPERATION.

The preparation may be divided into that of the patient, the room, the surgeon and his assistant, and the instruments, dressings, etc.

Preparation of the Patient.—In order properly to study the patient and learn the condition of his various organs it will be necessary that he be under observation for several days prior to operation. During this period attention must be directed to the correction of any disordered function and to the prevention of such indiscretions in diet and behavior as may be detrimental to the operative success. During this period, as has been already indicated, a careful examination of heart and lungs, a chemical and microscopic examination of the urine, and in certain cases an examination of the blood, should be made. Neglect of this rule may not always result disastrously, but if it is neglected habitually, the operator is sure to lose a certain number of cases from his carelessness. The time to find out a serious lesion of the heart or kidneys, for instance, is not during or after the operation, but before it. To fail to take the necessary precautions before operation is to render the operator liable for damages in a court of law; therefore, if for no other reason than his self-protection, a surgeon should not neglect this part of the preparation for operation. The volume of urine which the patient passes should be measured, and the amount of urea excreted also determined. It has been shown by Da Costa that in the presence of a small excretion of urea the danger of the anesthetic is markedly increased. During the few days previous to operation the patient should partake of an easily digested diet, and should exclude any excessive amount of alcohol or any especially rich food; the bowels should be opened thoroughly at the beginning of the preparation, and again on the day previous to operation. On the morning of the day of operation the rectum should be emptied by an enema. The night before the operation the patient should have a light, soft, easily digested supper, and, if the operation is to be done in the early morning, nothing but water should be taken into the stomach after this meal. If, on the contrary, the operation is to be done at midday or in the afternoon, the patient can be allowed liquid nourishment up to within five or six

hours of the operation, and water in moderate amounts up to within an hour or two. It is a great mistake to withhold water in liberal amounts during this period of preparation. If the patient is able to use a commode or go to the toilet prior to his operation, it is well to allow him to do so. Many patients are unable to void urine in bed, especially when they are nervous and worried about the approaching operation. It is a mistake to catheterize these patients unless there be some special reason for doing so. They should be allowed to rise and empty the bladder.

During the preparation period the patient should be thoroughly protected by warm clothing from drafts and cold atmospheres. It has long been a custom in many hospitals to remove all the patient's clothing on his admission and dress him in a suit of cotton pajamas or simply a muslin night-shirt with trousers, and allow him in these thin clothes to move about the wards. This is not what the patient has been accustomed to do, and it is a mistake to expose him in this way. He should either be kept in bed, or else dressed in warm clothes if he is to be up and about.

Frequently patients are in a nervous state prior to operation, and are unable to sleep. When this is the case, unless there is some special contraindication, some mild hypnotic, like the bromids, trional, veronal, or sulphonal, should be given, so as to give the patient sleep and rest on the night before the operation.

During this preparatory period the patient's pulse, temperature, and respiration should be taken at regular intervals, at least twice a day. As many of the lung infections and infections of the gastro-intestinal tract can be traced to the mouth, it is important that the condition of the mouth should be investigated, and dirty or decayed teeth cleaned or repaired. A daily warm bath should also be given, and the condition of the patient's scalp investigated and corrected, especially in children of the poorer classes, in whom parasitic diseases of the scalp are so common.

Preparation of the Field of Operation.—The elaborate preparation of the field of operation which was employed a few years ago has been replaced by a much simpler and just as satisfactory a technic. In addition to a general warm bath on the night before operation, the field of operation, which should include all parts which by any chance may be exposed during the operation, should be shaved in case any hair is present, and should be scrubbed for ten minutes with a soft brush or with a gauze sponge, using tincture of green soap. Formerly many surgeons applied a green-soap poultice which was allowed to remain for a number of hours, but this is unnecessary unless the skin is especially dirty or very thick. The application of such a poultice often produces a dermatitis, and thus thwarts the very object for which it was employed. In children, especially, because of their delicate skin, the application of a moist bichlorid dressing for any length of time is contraindicated, and in very old and feeble patients it should not be used because of the danger of exposure. After having scrubbed the

field thoroughly with warm water and green soap, alcohol (75 per cent.), benzin, or ether should be applied for the purpose of removing all grease from the skin. Of these three agents, personally I prefer alcohol. Following this the field should be scrubbed for four or five minutes

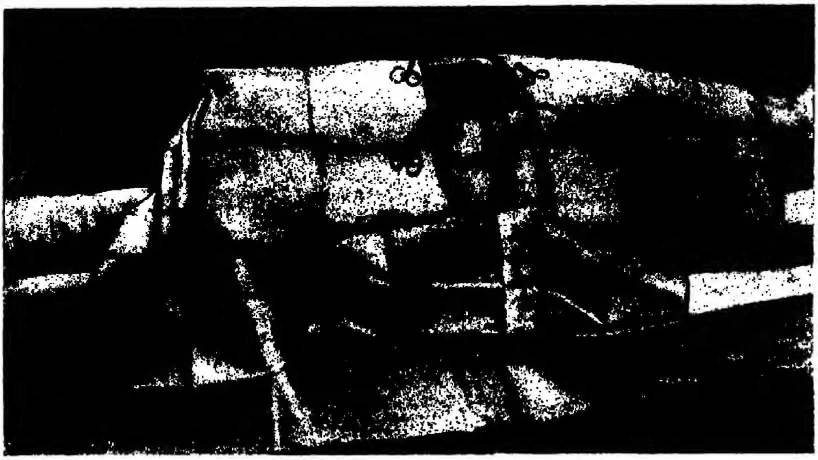

Fig. 210.—Field of Operation Surrounded by Towels Fixed by Hemostatic Forceps.

with bichlorid solution 1 : 2000, after which a dry sterile gauze dressing should be applied over the whole area and firmly fixed with a bandage. It was formerly the invariable custom to apply a moist bichlorid dressing and leave it in position all night; this, however, I believe to be unneces-

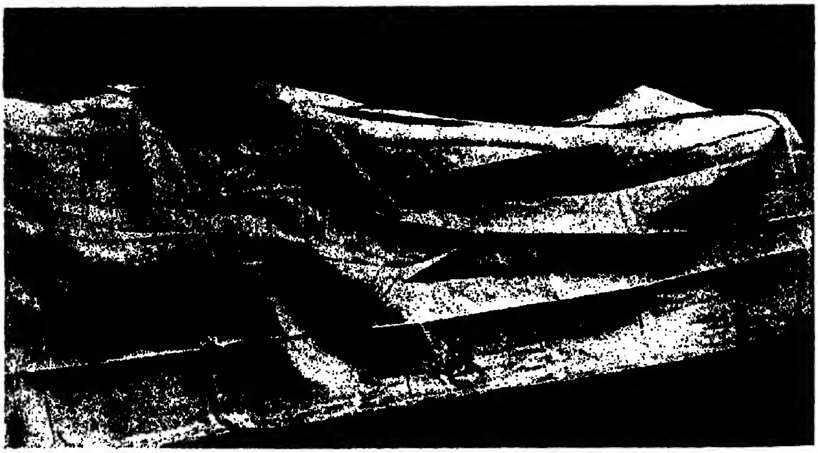

Fig. 211.—Sheet with Opening over Site of Operation.

sary, and when it is used about the trunk, that it not only makes the patient uncomfortable and disturbs his sleep, but it may be the means of chilling his body and exposing him in this way to cold. On the morning of the operation the dry dressing is removed and the previous preparation repeated. At this time, however, if it is desired,

a moist bichlorid dressing may be applied and allowed to remain until the patient is placed upon the operating table. Where the operation is to be done upon the hands or feet of laborers, or those who are accustomed to work in oil or grease, the immediate preparation for operation should be preceded, where time is allowed, by prolonged soaking of the part in hot soapsuds, or a green-soap poultice may be applied for some time. Although the scalp often requires repeated preparation, care should be taken not to apply very strong antiseptic solutions for any length of time, as irritation, especially of a scalp which is unaccustomed to cleansing, is apt to result.

Some years ago Murphy,[21] of Chicago, advised the use of an adhesive rubber dam as a protection to the patient's skin in operating. The dam was applied over the field of operation, and the incision made through it just as if it were one of the component parts of the skin. He writes me now, however, that he has given this up and is using a solution of 4 per cent. by weight of gutta-percha in acetone, only the resinoid of the gutta-percha being dissolved. This leaves a thin coating of rubber on the skin. He states that for a long time he used it on his hands also, but that it finally produced, through an erroneous addition of formalin by the manufacturer, an eczema, since when he has been unable to use it even without the formalin on account of the irritation. It does not in any way affect the patient's skin, and Murphy thinks that it entirely does away with the danger of infection from this source.

Emergency Preparation.—It often becomes necessary to operate in emergencies when there is little time for preparation either of the patient or of the field of operation. In certain cases, for instance, where profuse hemorrhage is taking place, either concealed or open, it is often a difficult question to decide how much time to devote to preparation. If a general anesthetic is to be used in such a case, the preparation of the field of operation can usually be done while the patient is taking the anesthetic, and in this way no time is lost. Where there is every evidence of severe hemorrhage, the first indication is to arrest the bleeding, and this should be done as speedily as possible. If the bleeding, however, is taking place slowly, the additional ten minutes required for the proper preparation of the skin is probably well employed in this way, and may save the patient a possible fatal infection. It can readily be seen that in a stab-wound of the heart or of a large vessel the patient might easily bleed to death while the field of operation is being prepared. In such cases as these the operation should be proceeded with, and after the hemorrhage is controlled, an antiseptic of some kind, preferably bichlorid of mercury solution, 1 : 2000 to 1 : 4000, should be used in and about the wound. In other words, an antiseptic instead of an aseptic operation is done. Also in these cases the application of a moist bichlorid dressing to the wound after it is closed is good practice. There are few instances, excepting where hemorrhage is present or respiration is obstructed, in which operation without some preparation of the field is justifiable. I believe that not infrequently the mistake is made of making an emergency out of certain surgical

lesions where operation might easily be postponed until the patient could be removed to proper environment and some preparation for it made. A few hours often make very little difference in the result, and the observation and the better study of the case which can be made in this time will frequently throw considerable light on the case, and possibly alter one's view regarding the lesion itself. Notwithstanding all these facts, it is often necessary to operate at once, and when this is the case, the field of operation can be shaved and prepared as already described, while the patient is being anesthetized, if there be not sufficient time to do it before. If it is desirable that the bowels should be moved, a high enema can be given, and this will usually result in the complete evacuation of the rectum.

Probably one of the most common conditions demanding prompt operative interference and emergency preparation is obstruction of the bowels. A patient suffering from this condition will often have fecal vomiting, and it is a good plan to wash out the stomach before operating. This serves three purposes—that of preventing the possibility of the patient drowning in his own vomit during or after the anesthesia, of lessening the likelihood of pneumonia due to inspiration of vomited material, and of rendering postoperative vomiting much less likely. Too much stress cannot be laid upon the advantages of gastric lavage in these cases.

Where it becomes necessary for any reason to operate in improper surroundings, as for bleeding or obstruction of the respiratory tract, no formal operative procedure is justifiable; the operator should go only so far as to render his patient safe for transportation to proper surroundings. When one is likely to be called upon to treat emergencies, especially injuries, he should always have at hand a bag with properly sterilized instruments, dressings, and appliances. This bag should be reserved for emergencies and not used for regular dressings, or else important articles are sure to be missing when most urgently needed. This will obviate greatly the danger of infection and greatly increase the surgeon's usefulness in such emergencies.

In an emergency operation, if there is no way or opportunity of sterilizing instruments by means of heat, they can be placed in a carbolic solution or in pure alcohol. If sterile catgut sutures are not at hand, ordinary silk or linen thread may be boiled and used. Dressings can usually be prepared by boiling linen, such as shirts, sheets, or handkerchiefs, or cheese-cloth while the operation is in progress, or these materials can be soaked in a bichlorid or carbolic solution. A sufficient number of towels and sheets should also be sterilized by soaking in these solutions. In the absence of proper assistants as quick and concise instruction as possible should be given to some intelligent layman regarding the help expected of him, and he should be particularly instructed, after the sterilization of his own hands, regarding the necessity of avoiding the handling of anything not already sterilized.

A surgeon should never lose sight of the fact that with an operation

performed in a properly arranged hospital operating room and under thorough aseptic conditions, although it may be performed a few hours later than one could be performed under far less satisfactory circumstances, the patient's chances of recovery are far better. One should not, therefore, make the mistake of considering many of the inflammatory lesions of the abdomen, thorax, and cranium emergency cases, and operate upon them under unfavorable surroundings unless the condition of the patient truly indicates them to be such.

Dressing and Transporting of Patients.—The greatest care should be exercised to avoid exposure and chilling of the patient during the few hours preceding operation, during transportation to the operating room, and more especially during and after operation. The parts that are not involved in the field of operation should be warmly clothed; the patient's legs and feet should be covered by Canton flannel or woolen leggings or pajamas, and the entire body wrapped in several blankets. The head should also be hooded in a light blanket during transportation through passageways and in elevator-shafts. This protection should be kept up during the administration of the anesthetic, and when the patient is placed upon the operating table it should not be neglected. It is too often the custom in abdominal operations to keep only the legs of the patient wrapped in a blanket, allowing the chest to be absolutely exposed to air and fluids which too soon become cool. A light blanket or woolen shirt should always encase the chest. The blanket which is over the lower extremities should come up as high as possible without interfering with the field of operation. In other words, only so much of the patient should be exposed on the operating table as is positively necessary. Various methods of keeping the patient warm on the operating table have been devised: Crile's hot-water mattress is shown in Fig. 253, p. 938, Vol. I. Other surgeons have their tables heated by electric lights which are distributed on the under surface of the table. Personally, I believe that if the patient is properly prepared beforehand, and if the surgeon and his assistants are careful not to allow the clothing to become saturated with fluids, there will be no necessity for any of these specially devised tables. If, on the contrary, it is the custom with the surgeon to use large quantities of fluids, then some such method of heating the table is of great value.

CHOICE AND PREPARATION OF OPERATING ROOM.

In building an operating room in a hospital three things should be kept in mind: (1) A good supply of light; (2) having the room well separated from the wards and patients' rooms; and (3) communicating dressing rooms for the surgeons and nurses and etherizing rooms for the patients. In addition to this a most valuable adjunct is a recovery ward, where patients are allowed to recover from their anesthetic before being removed to the wards: of course, this is unnecessary where patients are returned to private rooms. The sterilizing room and the instrument room should also be close to the operating room. An

overhead light from a skylight well protected from breakage by a wire screen under it is much to be preferred to side lights. The skylight and the wire protection should be easily accessible for the purpose of cleaning, and should be cleaned at frequent intervals. If there is a good skylight, side lights are not necessary, but are often, especially in perineal work, a great convenience. Ample arrangements should be made also for artificial light, and for this purpose electricity is much to be preferred, as it is much less dangerous and much cleaner than gas. Various methods of lighting an operating room artificially are employed. The best light is obtained from an overhead collection of incandescent lights. Such lights should be easily reached and be cleaned each day to protect the field of operation from falling dust. Reflected light is also employed in some operating theaters. The light is directed against a mirror which throws it onto the field of operation. Another method is to have lights placed at different points around the room, with metallic reflectors behind them. None of these methods, however, compares in satisfaction with the overhead light, and their only advantage over the latter is the fact that they cannot in any way infect the wound. If care is taken, however, the chances of infection from an overhead light can be reduced to practically nothing. It is well to have some substitute to fall back upon in case of failure of the electricity. I have known of two instances in a suburban hospital where the electric lights failed in the midst of an abdominal operation. The best substitute for electricity, in case there are no gas-fixtures in the room, is simply a collection of candles, which can be congregated on a board, and this can be held in different positions. Kerosene lamps are dangerous and often result in serious accidents. Candles should always be at hand ready for use in case of emergency.

Fig. 212 shows an arrangement of an operating room, dressing rooms, etherizing rooms, etc., which is convenient in a hospital. (See also the chapter on the Surgical Organization of a Hospital.)

The choice of an *operating room in a private house* is often easy from necessity, but the preparation is always unsatisfactory. The advantages of operating in a well-appointed operating room in a hospital are innumerable, and no operation of magnitude should be done in a private house unless from absolute necessity. Even in apparently simple operations there often arise emergencies when one wishes for the conveniences and resources of a modern operating room. If the surgeon could always know exactly what he was going to do, and exactly what emergencies and dangers would arise, probably operations in private houses would be more satisfactory, but this he can never know, and consequently when operating in private houses he naturally meets with disappointments and is unable to do as satisfactory work as he could under proper environment. It is not only in behalf of the surgeon, but much more in behalf of the patient, that this plea for the hospital operating room is made. The public should be educated to the idea that a surgeon does far better work, and is much better equipped for the emergencies which may arise in even the simplest opera-

tion, when operating in his own hospital and surrounded by his customary nurses and assistants. Only when absolutely driven to it by the patient's serious condition should a surgeon be willing to operate in a private house when a well-appointed operating room is at hand. Certain minor and emergency operations, however, must be done in private houses. The only way to do this satisfactorily and successfully is to make a thorough preparation for every possible contingency and have all needed trained assistants. As a matter of fact, most of the operations that are done in private houses are done with fewer assistants than are in a hospital, and yet without any of the con-

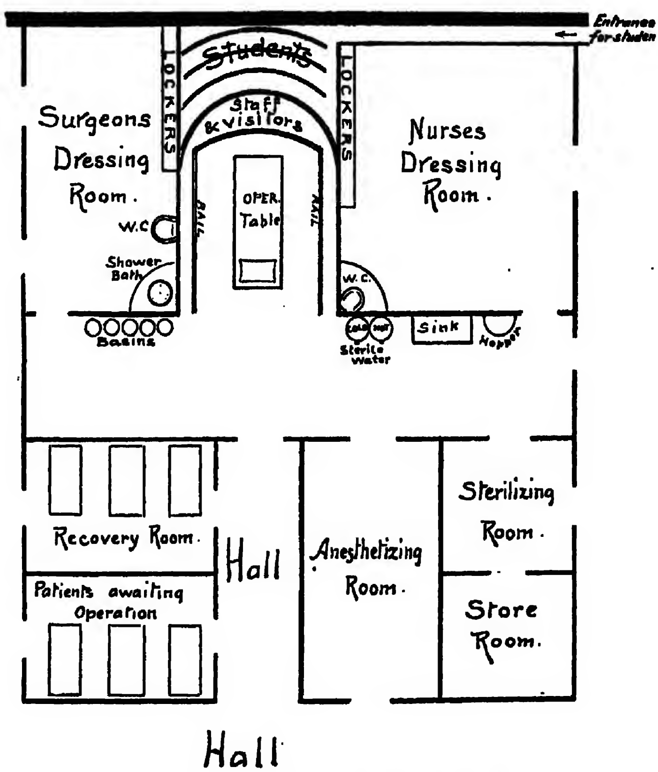

FIG. 212.—A CONVENIENTLY ARRANGED OPERATING SUITE.

veniences of the hospital. It is not surprising under these circumstances that the work itself is not so well done nor the results so good.

In choosing a room in a private house one should be selected which offers the best light at the time of day the operation is to be undertaken. If possible it should adjoin, or certainly be on the same floor with the patient's own room. If possible, the operation should never be done in the patient's room unless he is first moved out. All heavy hangings, pictures, unnecessary furniture, together with carpet and rugs, should be removed from the room. The walls should be wiped down and the floor scrubbed. In an emergency it is better not to stir up a great deal of dust

and dirt in a room where an operation is to be done, unless there is plenty of time thoroughly to clean it; therefore, under these circumstances the carpet should be covered with sheets and the furniture wiped with a wet cloth. Occasionally it may be necessary to improvise an operating table, and for this purpose two small tables placed end to end are often preferable to a longer table, such as the proverbial kitchen table, which is recommended, because the latter is nearly always too wide to render handling of the patient and the necessary operative manipulations easy. Another simple method is to place a wide board from one small table to another. The improvised table should be covered with a folded blanket and this covered by a sheet. A method of improvising the Trendelenburg table is shown in Fig. 213. Numerous portable operating tables are on the market. Finney, of Baltimore, has devised an operating trunk for operations in private houses, which not only is used to transport instruments, dressings, etc., but which also can be

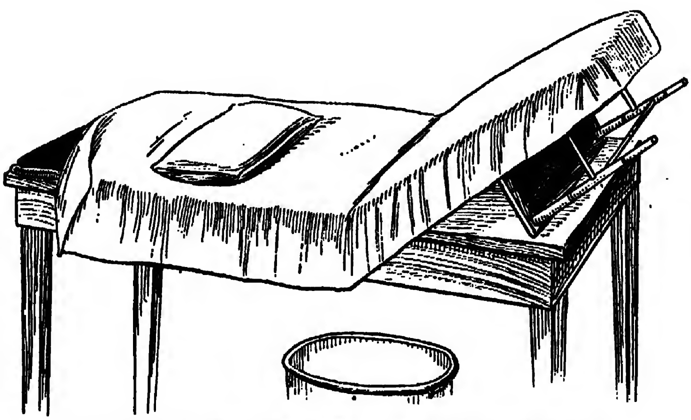

FIG. 213.—AN IMPROVISED TRENDELENBURG TABLE (Brickner.)

converted into a very satisfactory operating table (Fig. 214). In order to avoid soiling and wetting of the patient an ample amount of rubber mackintosh should be provided, which can be folded in such a manner as to confine the fluids and drain them into a bucket. Rubber pads are made for this purpose, but they are objectionable because of the difficulty in keeping them thoroughly clean. When used, they should be scrubbed and sterilized before and after each operation.

In addition to the operating table three other small tables should be obtained, scrubbed, and covered with sterile sheets. An ample supply of basins, buckets, and pitchers should be at hand; those which are to contain solutions used in the operation should be first soaked in a bichlorid solution or boiled. Sheets and towels should also be sterilized by boiling or being soaked in and wrung out of a bichlorid solution (1 : 1000). In case instrument trays are not at hand, meat dishes or soup plates can be used for this purpose. They can be readily sterilized by soaking in a bichlorid solution. The arrangement of tables, instru-

ments, etc., should be as much like the operator's accustomed hospital arrangement as possible. Fig. 224 gives an arrangement which will be found satisfactory in most instances.

The only way thoroughly to prepare for an operation in a private house is to go carefully over the various steps of the operation beforehand and consider every possible need and emergency. An ample supply of hot water and hot and cold boiled water should be provided. One of the last things in the preparation is to see that the room is of the proper temperature—about 75° F. The possibility of obtaining this temperature should be considered before deciding upon the room.

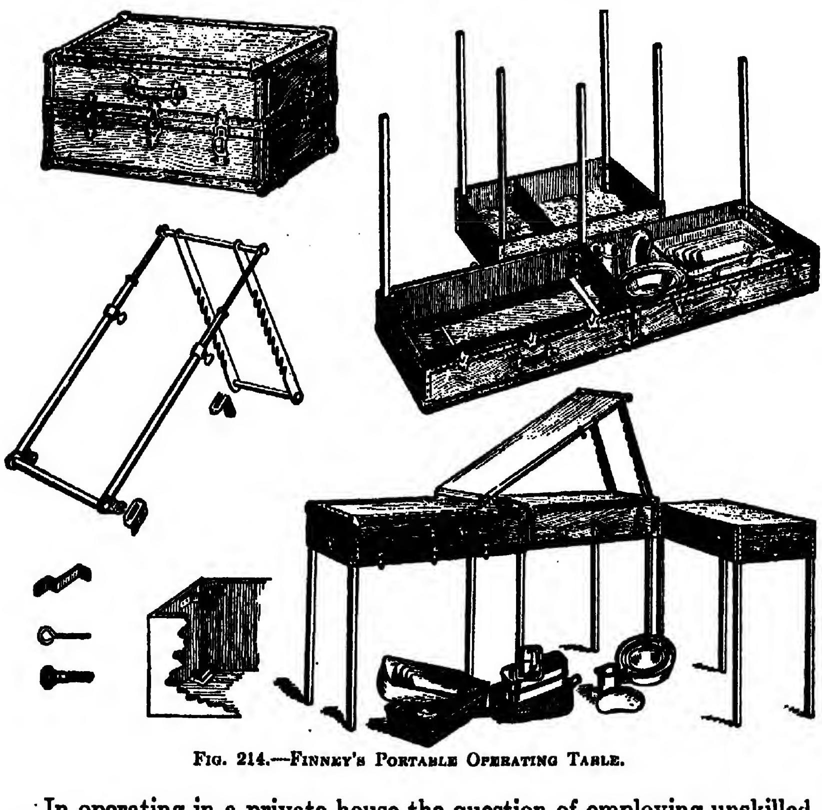

FIG. 214.—FINNEY'S PORTABLE OPERATING TABLE.

In operating in a private house the question of employing unskilled assistants often arises, and the surgeon should endeavor to choose one or two intelligent persons who have possibly witnessed operations and who are not likely to lose their heads or faint at the sight of blood. Excepting for these chosen assistants, the room had best be free of all the family and friends. The operator will do better work if they are not present, and there will be much less chance of wound infection, as the average layman has absolutely no conception of surgical cleanliness. It is a great mistake to allow members of the patient's family or close friends, unless accustomed to witness operations, to be present. The surgeon who permits this is sure to regret it. If sudden hemorrhage or

other accidents happen, especially anesthetic accidents requiring a cool head and prompt action, the presence of these friends or relatives is the greatest drawback; therefore, for the patient's own benefit, as well as for the surgeon's, it is wisest to exclude them.

PREPARATION OF THE SURGEON.

It must be understood that the preparation required for the surgeon is also required in every detail for the assistants and nurses. These can infect a wound nearly as easily as the surgeon himself. A chain is no stronger than its weakest link, and a nurse who handles sponges, sutures, and ligatures is an important link in the operative technic. There has been in recent years a tendency to simplify as far as possible the preparation of the surgeon for an operation, and the complicated and cumbersome details that were formerly gone through with have now been abandoned.

It is important, in the first place, that the surgeon should be cleanly in all his habits and dress. Slovenly dressing and unclean linen hardly suggest a perfect surgical technic, and it is difficult to imagine such an one performing an absolutely aseptic operation. The surgeon's hands should always receive his particular attention. The nails should be cut short, and cracks, hang-nails, and abrasions should be avoided, as they constitute a good nidus for the development of germs. When, for any reason, it becomes necessary to use strong antiseptics which produce roughening of the skin, care should be taken to wash the hands in sterile water immediately. The combination which is sure to produce roughening and irritation of the hands is that of blood and bichlorid solution; carbolic acid and formalin solutions have much the same action, and should always be washed off promptly with sterile water. Should the hands become chafed or roughened, some bland hand lotion should be thoroughly applied at night, and, if necessary, a thin cotton glove worn at night until the condition is relieved. Internes and nurses whose hands are constantly in irritating antiseptic solutions should keep such a lotion in their bedrooms and use it regularly. The habit of scraping the under surface of the nail with a sharp metal instrument for the purpose of removing dirt is a mistake, as it keeps the nail rough and makes a good surface for the lodgment of dirt. If the nails are kept short, nothing more need be used for cleansing the under surface than a nail-brush or an orange-wood stick.

At the present time, when automobiles are so commonly used by those doing surgical work, the greatest care should be exercised to protect the hands from grease and oil, which render them difficult of sterilization. By the free use of gasolene or benzin most of this oil and grease can be removed. The habit of wearing gloves does much to protect the hands from the ordinary dirt and abrasions which accompany any mechanical work.

Fortunately for surgery, the day of long hair and long beards has passed, and an operator should always be careful not only that his

hair and his beard, if he wears one, are properly trimmed, but also that all skin which is covered by hair is kept thoroughly clean. The perspiration which may possibly drop from the head or face is always more or less septic, and may readily be the source of wound infection.

The mouth of the surgeon should also be kept in as cleanly a condition as possible. The teeth should be cared for regularly, and the tonsils kept free from infection. Even in dressing wounds the surgeon is apt to talk, and it is often impossible to prevent the escape of saliva, which may result in wound infection. To prevent this during

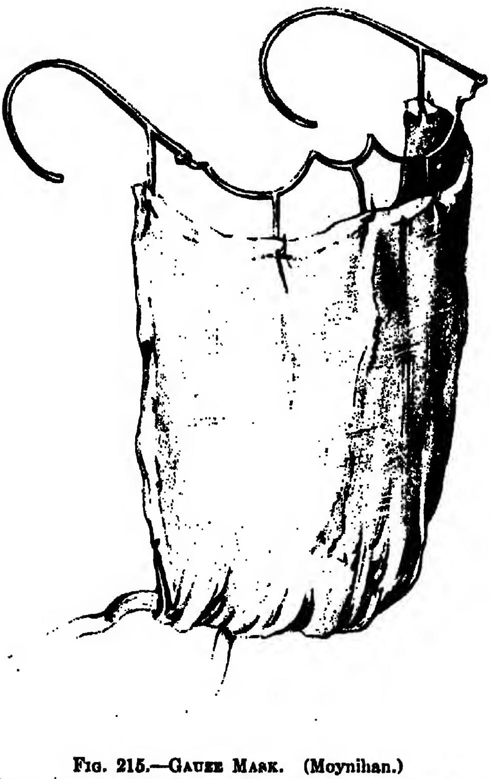

Fig. 215.—Gauze Mask. (Moynihan.)
The gauze is suspended on hooks dependent from a spectacle frame.

Fig. 216.—Surgeon Prepared for Operation Wearing the Spectacle Mask. (Moynihan.)

the conduct of an operation a mask of gauze may be worn over the mouth, as is shown in Figs. 215 and 216.

The **immediate preparation** consists, first, in a change of all the outer clothing, and preferably all the underclothing. Aside from the cleanliness of this change, the comfort of the surgeon is to be considered. This change of clothing should also apply to the nurse. Nothing is more uncomfortable than to have one's mind distracted by an uncomfortable collar or tight shoes while operating. Another great advantage

of the change of clothing is that when the surgeon is through operating he puts on clean, dry clothing, and is much less apt, in going out into the open air, to catch cold. A change of shoes will also be found a great convenience, and most surgeons wear white canvas shoes, which are readily cleansed. The operating suit which is worn by the surgeon and his assistants should be made of a heavy, durable material, which will stand repeated washings and sterilizations. The ordinary white linen trousers and shirt or a suit of pajamas may be used, but a suit

FIG. 217.—SURGEON'S OPERATING GARB.

FIG. 218.—OPERATING GARB FOR NURSE.

made of more durable material and fewer buttons is preferable. This suit should not be used in lieu of an operating gown or apron, since it is sure to become contaminated while being put on and during the cleansing of the hands. When the sterilization of the hands is complete, a sterile gown should be put on, and preferably one with long sleeves over which the cuff of a rubber glove can be drawn.

Preparation of the Hands.—The preparation of the operator's hands has received more attention than any other one point in aseptic technic, and deservedly so, for the hands are the most common source

of wound infection. Innumerable methods and solutions have been employed, and at the present time no uniform method has been established. It is true, however, that here again simplicity has supplanted to a large extent complicated and cumbersome procedures. In all the many different methods the mechanical cleansing with clean warm water and a scrubbing-brush constitutes the first part of the preparation, and in the minds of most surgeons it is the most important part. It is necessary to know how and how long to scrub the hands. It is per-

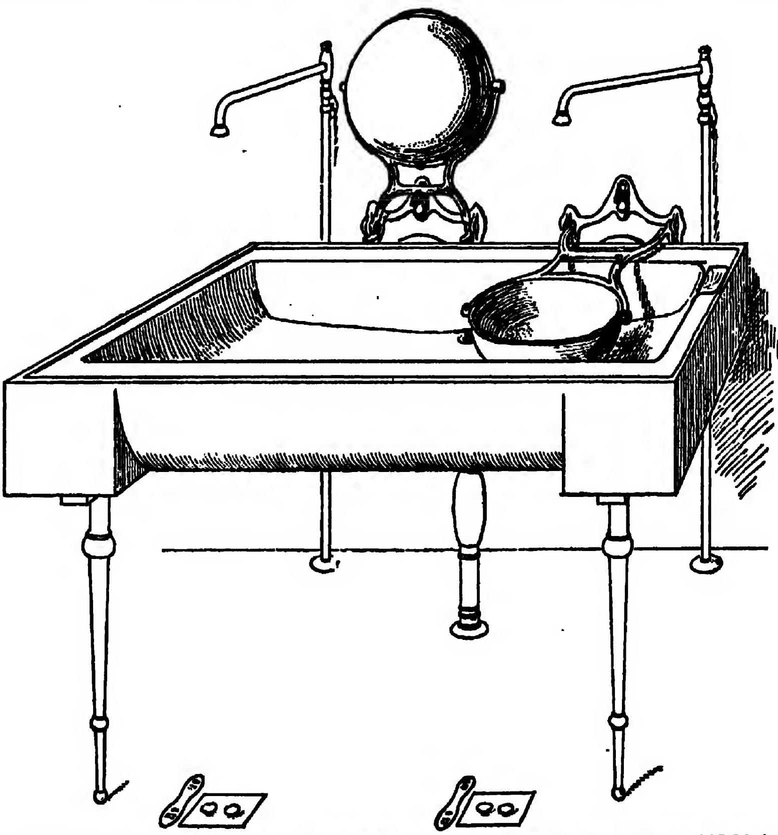

FIG. 219.—ARRANGEMENT FOR WASH-BASINS IN PRIVATE HOSPITALS. (Kelly and Noble.)
The basins are placed over a large porcelain sink and filled with water by means of Robb's pedals. Each basin swings in its frame, and is emptied into the sink by a light touch on the rim. When out of use the basin and frame are hooked up against the marble slab on the wall, as shown on the left.

fectly true that one person may scrub the hands for twenty minutes without getting them as clean as another would in ten. Nurses and assistants should all be taught to scrub every part of the hand and forearm, special attention being devoted to the nails and the spaces between the fingers and to the back of the forearm. The posterior aspect of the forearm is one which is very commonly overlooked, and yet it is one which comes in constant contact with the sterile towels and sheets surrounding the field of operation. The hands should be

scrubbed both in the closed and open position, so as to remove dirt from all the creases. The under surface of the nails should not be scraped with a metal instrument, but cleansed only with the nail-brush or a sterile orange-wood stick. The brush which is used should not be too soft nor yet too hard, and its bristles should be perfectly even, otherwise they are apt to cut the delicate skin between the fingers or under the nails. The brush should be sterilized before being used. It is a great mistake to use the same brush in preparing for an operation that is used for cleansing the hands after ordinary dressings or after conducting operations in the presence of sepsis: these latter brushes should always be sterilized and kept in an antiseptic solution. A very simple way to avoid confusing the two brushes is to use brushes with black bristles for scrubbing the hands to cleanse them from dirt, and a sterilized brush with white bristles to disinfect the hands. Some surgeons prefer to use gauze sponges during a part of the time devoted to the hand sterilization instead of brushes, and no doubt if properly employed the gauze accomplishes the same object. I cannot believe, however, that its use is as effectual about the nails. During the scrubbing of the hands the surgeon should not handle the spigots or drain plugs. If it is necessary for him to manipulate these, they should be covered with a sterile gauze pad. In most modern operating rooms the spigots and the stops are regulated either by the foot or by a lever which is worked by the knee. The water which is used should preferably be sterile: ordinary filtered water, however, which is warm, may be employed.

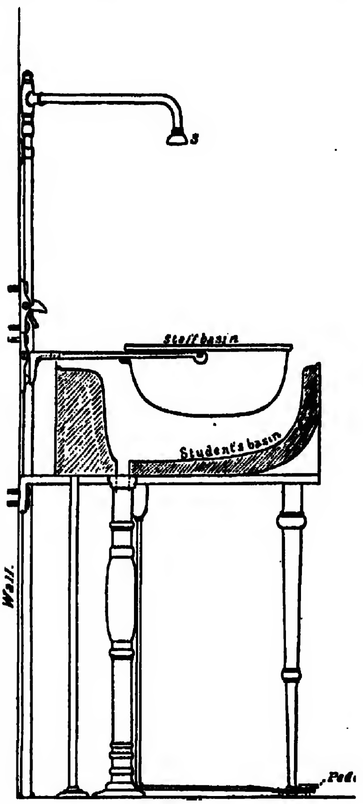

FIG. 220.—THE ARRANGEMENT OF THE HAND BASINS AT JOHNS HOPKINS HOSPITAL. (Kelly and Noble.)

The metal basin used by the operator and house staff is set in a frame which can be elevated as in Fig. 219. The basin is pivoted and easily lifted off from the frame and put in the steam sterilizer before using. Beneath this is a second basin, a porcelain fixture, which is used exclusively by the students before making vaginal examinations, etc. The spray (*s*) is adopted from the Royal Victoria Hospital operating room.

The water should be changed at least three times during the preparation. That soap is best which is least irritating, and most of the antiseptic soaps cannot be employed for any length of time because of their irritating quality. Tincture of green soap or "Ivory" soap is the least irritating and answers every purpose. After all, it must be remembered that it is the *soak*, and not the *soap*, as has been said by a Scotch

surgeon, which accomplishes the object. Warm water softens the skin and enables it to be thoroughly cleansed.

The time devoted to this mechanical cleansing should be at least ten minutes, and preferably fifteen, and an important point is that the time should be divided equally between the two hands. The time devoted to this scrubbing should not be guessed at, but must be accurate. I have seen more than four-fifths of the time devoted to one hand. Nurses and internes, unless carefully watched and trained, are very apt to shirk this thorough mechanical cleansing: its importance should be impressed upon them and they should be made to scrub as long and as carefully as the surgeon himself. I have often observed a surgeon devote the requisite time and attention to the scrubbing of his hands, and his nurse or assistant complete this operation in one-third the time and with one-third the care. Of course, it is unnecessary to devote the same amount of time to the mechanical cleansing of the hands when passing from one operation directly to another unless the hands have become contaminated during the preceding operation or during the interval. Such contamination, however, unless carefully avoided, is apt to occur on the part of the assistants and nurses.

Chemical Sterilization of the Hands.—After the proper mechanical cleansing, any one of a number of chemical methods may be employed to complete the sterilization. The simplest, and that which I can heartily recommend, is soaking the hands in a 60 or 75 per cent. solution of alcohol for about five minutes. This may be supplemented by soaking in a 1 : 2000 bichlorid solution for the same time. The alcohol, however, is more penetrating and much less irritating than the bichlorid solution.

Another method of chemical sterilization is that of using permanganate of potash and oxalic acid, which had its origin at the Johns Hopkins Hospital, and was highly recommended for the destruction of the Staphylococcus epidermidis albus, which proved to be the organism which most frequently caused wound infection. After scrubbing the hands they are soaked in a saturated solution of permanganate which stains a dark brown; the permanganate is then removed by washing in a saturated solution of oxalic acid. This method is very popular, but to the skin of many surgeons the oxalic acid is quite irritating. This irritation may, however, be relieved by washing in sterile limewater after using the acid solution.

Yet another method is the use of a combination of chlorid of lime and soda. A scant tablespoonful of chlorid of lime is placed in the palm of the hand; to this is added a piece of sodium carbonate about the size of a walnut, and sufficient water to make a paste. This is rubbed into the parts until the rough grains of the chlorid disappear. The hands are then washed with sterile water.

An enormous amount of experimental work has been done, and innumerable methods of chemical sterilization have been suggested. I cannot help but feel, however, that the mechanical cleansing is by all means the most important, and that the simplest supplemental chemical sterilization is the best, and for this purpose I recommend

most heartily the alcohol method. Among those who have done a great deal of work in this line is Charles Harrington,[22] of Boston. A solution which has been extensively employed, and which is known as Harrington's solution, consists of commercial alcohol, 640 c.c.; hydrochloric acid, 60 c.c.; bichlorid of mercury, 8 gm.; water, 300 c.c. This solution is very actively germicidal, but is very irritating to some skins, and for that reason many surgeons have had to give up its use. One point which Harrington has brought out is that, after the proper sterilization of the hands, the secretion of the sweat-glands which may occur within a short time is sterile. In a long operation, or where the hands perspire freely, too much confidence should not be placed in this demonstration however, but the hand should be frequently washed in an antiseptic solution if no gloves are worn.

Rubber Gloves.—Probably no one element has contributed more to the perfection of aseptic technic than the introduction of rubber gloves. The use of these by many surgeons was for a long time confined to work on infected cases, but at the present time, in nearly every clinic, surgeons will be found to wear gloves in all their work. Gloves not only serve to prevent infection of the wound, but also they protect the surgeon against infection. In office and general practice rubber gloves are indispensable, and should always be worn when vaginal and rectal examinations are made. Their use in the office enables the surgeon to make the necessary examinations and go at once to the operating room with no fear of infecting the wound. In operations where it is necessary to make examinations of the mouth, vagina, or rectum, or to place a finger in any of these cavities for aid during some operative manipulation, the rubber glove enables the surgeon himself to do this part of the work without any fear of contaminating the wound, as the glove which is used for this purpose can be immediately removed and replaced by a sterile one. The gloves should be made of thin rubber, and preferably pebbled or roughened on one side. This roughening does away with one of the early objections made to rubber gloves, namely, that it was difficult to hold instruments and serous-covered viscera like the intestine. A rubber glove should fit snugly, as no delicate work can be done with a glove that is too long or too wide inthe fingers, as the wrinkles which occur are very troublesome. A glove which is too tight produces nearly as much inconvenience as one which is too loose, as it constricts the hand, rendering manipulation more difficult, interfering with sensation, and, after a time, producing marked aching of the hands. Thicker gloves may be used for bone-work or where delicacy of touch is not required. In using the thicker gloves for these cases there is great economy, as gloves are very expensive and the thin ones are easily torn in bone-work.

Sterilization of the gloves is a very simple matter, but an important aid in this is the habit of never allowing a glove to remain soiled or wet for any great length of time. As soon as it is removed from the hand it should be thoroughly washed in soap and water and boiled for five to fifteen minutes, depending upon whether it has been used in a clean

or an infected wound. The repeated boilings do much to injure the rubber, but what is more injurious, is allowing the glove to remain wet for any length of time. Where immediate sterilization after use is not practicable, the glove should be thoroughly cleansed with soap and water, dried, and dusted with talcum powder, which prevents the surfaces of the glove becoming adherent to one another. The repairing of rubber gloves is an economic measure which should always be practised. A puncture in a finger can be repaired by stretching the glove over a small test-tube and applying a patch of thin rubber by means of one of the cements similar to that used for repairing bicycle and automobile tires and sold by all dealers for this purpose. Sterilization does not affect the cement. The patch should preferably be placed on the inside of the glove, so that it may not by any chance become displaced

FIG. 221.—AN EASY METHOD OF PUTTING ON A GLOVE.

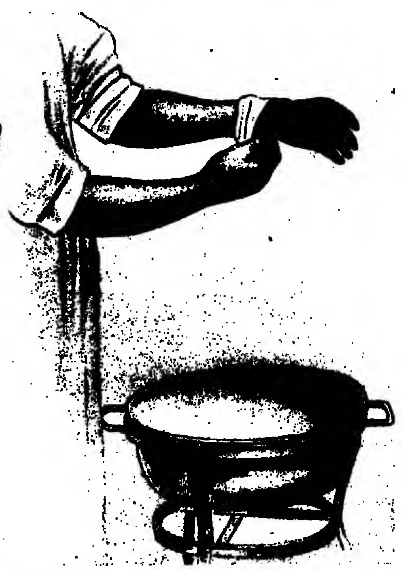

FIG. 222.—PLACING GAUZE UNDER WRIST-BAND OF GLOVE TO PREVENT ESCAPE OF SECRETION OF THE SKIN.

and lost in the wound. After sterilization the gloves should be thoroughly dusted with an aseptic powder, and folded in a sterile cloth or towel. Before being used again they should be resterilized.

There are two methods of drawing on the gloves—one is the wet and the other is the dry method. The dry method consists in thoroughly powdering the glove with some sterilized powder, like talcum, and rubbing the same well into the hand. If preferred, the glove may be powdered on its inside and constricted at the wrist with a rubber band and then boiled. The wet method is the one which I employ and believe to be preferable. The glove is about half filled with sterile water, the cuff turned back and stretched by a nurse while the hand of the operator is thrust into is. Fig. 221 shows this method of putting on the glove, and if it is followed, there will be little chance of tearing

the glove. The glove can be easily peeled off if thoroughly wet first. If an attempt is made to remove it when it is dry or partially so, it is very apt to be torn. Another advantage of the wet method is that it discovers any minute holes which may be present in the glove and which may be overlooked when the dry method is used. Dudley P. Allen, of Cleveland, advocates putting on the glove out of bichlorid solution, as the amount of solution remaining in the glove is sufficient to sterilize any secretion from the skin. This method may be used occasionally, but if used habitually, it is very apt to produce considerable irritation of the skin. During the progress of the operation the hand should be rinsed frequently in sterile water so as to prevent the clotting of blood on the glove. It is a good plan to place under the portion of the glove covering the wrist a thin band of sterile gauze; this prevents the escape of perspiration during the progress of the operation; of course, this gauze is unnecessary where a long-sleeved gown is used and the glove is pulled up over the sleeve. The glove should not be put on until the surgeon is ready to begin the operation.

Because gloves are worn, *no operator should suppose that it is any the less necessary conscientiously to go through a sterilization of his hands*. Frequently, in the course of an operation, the glove is torn or punctured by a needle, and if proper preparation of the hands has not been made, infection of the wound may result.

At different times cotton gloves have been strongly advocated, and one of the special claims made for them is that they do not cause by their warmth an excessive secretion of the skin. Notwithstanding this advantage there can be no comparison in the safety of operating in rubber rather than in cotton gloves. The cotton glove has the marked disadvantage of interfering much more than the rubber glove with the tactile sense and the manipulation of the tissues. Keen[23] showed, some years ago, that the cotton glove possessed insurmountable objections.

Preparation of Instruments.—As far as possible only those instruments should be employed which can be sterilized by boiling. Wooden and ivory handles are to be discarded in favor of solid steel. As few corners and joints, and as little lettering as possible, should be the rule in the manufacture of surgical instruments. All metal instruments can be readily sterilized by boiling for ten or fifteen minutes in a 1 per cent. carbonate of soda solution. Occasionally, *e. g.*, in spinal anesthesia, the soda should not be used. This sterilization, however, should be gone through with twice, once immediately after, and once immediately before, operation. What has been said regarding rubber gloves applies particularly to instruments, namely, that as soon as the operation is completed, the instruments should *immediately* be cleansed by scrubbing with a brush and thoroughly dried or sterilized and dried. There is no excuse for allowing rust or tarnish to occur on a surgical instrument; if the instrument is thoroughly dried after being used and sterilized there will be no such tendency. Any tarnish or rust can easily be removed by any of the various fine sandsoap preparations.

After being sterilized the instruments may be placed in a tray and covered with sterile water or sterile normal salt solution, or they may be used dry, which I think is preferable. In this case they are spread

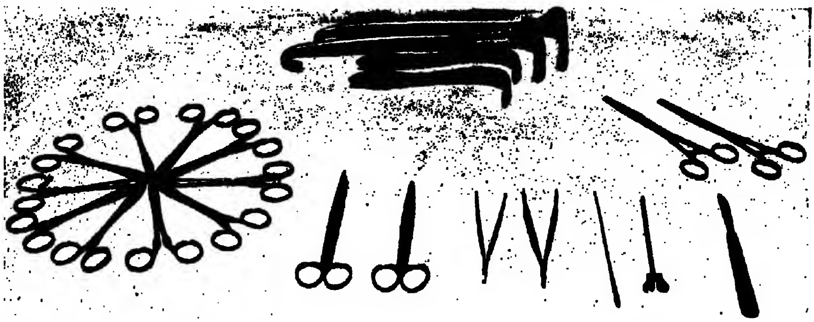

FIG. 223.—CONVENIENT ARRANGEMENT OF INSTRUMENTS FOR OPERATION.

out between sterile towels and arranged in some regular way so that those who handle them may know exactly where to find the desired instruments when needed. This arrangement of instruments should

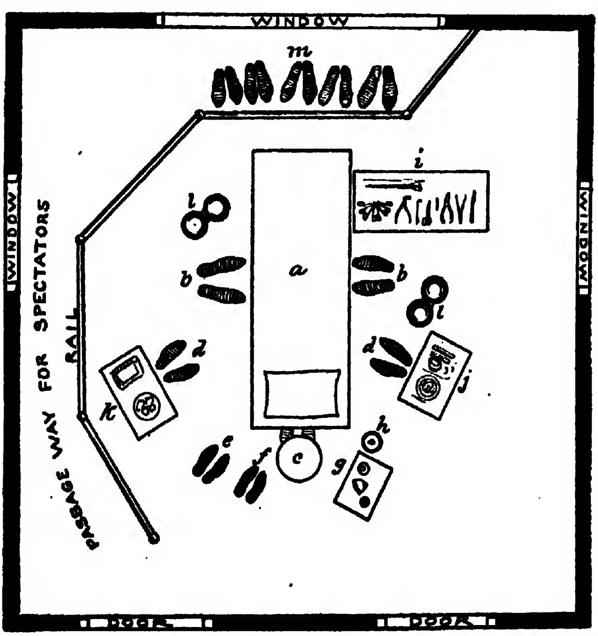

FIG. 224.—ARRANGEMENT FOR SURGEON AND ATTENDANTS.

a, Operating table; *b*, surgeon or assistant; *c*, anesthetizer; *d*, *e*, nurses; *f*, orderly or nurse; *g*, anesthetist's table; *h*, oxygen tank; *i*, instrument table; *j*, ligatures and sutures; *k*, sponges; *l*, basins; *m*, spectators.

be maintained as far as possible throughout the operation. The development of a regular method of arranging the instruments enables the operator to tell at a glance whether all instruments that are apt to

be needed are present, and it greatly facilitates the progress of the operation. In sterilizing knives the blades should be carefully wrapped in cotton to prevent nicking of the edges against other instruments. Boiling tends to dull the knives, and some operators prefer to use mechanical cleansing, and allow them to remain for some time in 95 per cent. alcohol. A convenient instrument tray is one which extends over the operating table, and is made very much like the tray used for feeding patients when in bed. This places the instruments in a readily accessible position. The instruments, especially hemostatic forceps and scissors, should be counted before and again after operation, to ascertain that none has been left in the wound, particularly in abdominal operations.

FIG. 225.—SPECTATOR'S GOWN.

The Operation.—A matter always to be considered is the disposition of assistants, nurses, and visitors. Every operator should have an established habit in regard to the work which each of his assistants and nurses is to do, and the positions they are to occupy during the operation. Fig. 224 shows an arrangement which I have always found very satisfactory, but each operator will develop an arrangement which best suits his circumstances and convenience. In the matter of visitors, their position during the operation should be definitely indicated, and they should be made to keep it. To have spectators moving around the operating table is very disturbing to the operator and his assistants, and increases the dangers of infection. When spectators are allowed to come anywhere near the operating table, they should be properly gowned so as to prevent any chance of infection. The operator should never become so engrossed in his work and in demonstrating its steps as to forget his patient's condition.

The Operation Itself.—An early consideration before commencing an operation is the position of the patient on the table—for instance, if it is desired that the patient should be placed in the Trendelenburg position at any time it should be ascertained that the bend of the knee corresponds to the joint in the table, and that the necessary precautions have already been taken to prevent the patient slipping.

The patient should not be anesthetized and no unnecessary exposure of the patient's body should be made for any length of time before the surgeon is ready to begin his work. If the final preparation of

the field of operation is done upon the table, it should be made with as little exposure and wetting of the patient as possible. Not infrequently I have seen patients placed on the operating table with nothing between the body and the glass or metal table but a thin sheet, and more frequently still with the arm hanging over the edge of the table in such a way that the musculospiral nerve may be pressed upon sufficiently to produce a palsy. A troublesome wrist-drop, which will long outlast the convalescence from a simple operation, or a pneumonia from exposure to cold on the operating table or during transit to the ward or room may result from neglect of these points.

The welfare of a patient after an operation depends not only on the skill and accuracy with which the operation is done, but also on the means employed during the operation to conserve his strength, maintain the normal resisting power of his tissues, and render his early hours after operation as peaceful and free from pain as possible. The operator who works regardless of time and the amount of anesthetic his patient is taking, or who pays no attention to the patient's posture on the table, the protection of the parts of the body not involved in the field of operation, or who uses large quantities of fluid regardless of whether it drains away properly or accumulates under his patient, is laying up for himself many postoperative complications which he who employs "speed without haste" and is thoughtful not only of the operation itself, but of his patient's condition, will seldom see. I do not advocate a want of thoroughness in operating in order to accomplish the closure of the wound in a certain number of minutes, or the constant shifting of the mind from the operation itself to the patient's condition, but I do mean that we should not drag an operation along over an unnecessarily long period, and that we should establish in our operating rooms a habit among our assistants and nurses of carefully looking after the comfort and condition of the patient.

Another important factor in the operative technic which has a marked influence on the prognosis is the way the tissues are handled. Unnecessary instrumentation or the *rough handling* of tissues is a potent element in producing postoperative pain and in predisposing to suppuration. All viscera should be handled with the *greatest gentleness,* and evisceration avoided whenever possible. Crile has shown how much all these manipulations add to, or produce, severe shock. The ligation of large masses of tissue, or the too tight constriction of tissue with sutures, produces the same results. A consideration should also be given to the position and extent of the incision. It should be such as to allow ample exposure of the part desired without, however, being unnecessarily long. Incisions which can be made in the normal folds of the skin tend to produce much less visible scarring than those which cross the normal folds. Muscular fasciæ and muscles should be divided, when practicable, in the line of their fibers, and not across them. Nerves of any size should always be avoided, and blood-vessels, if large enough to be identified, should be caught with forceps before being divided. The bleeding from the smaller blood-vessels, which at

first is profuse, nearly always ceases without any special hemostasis, and it is better to allow it to do so than to compress large masses of tissue in hemostatic forceps. In most operations I believe that it is not advisable to ligate all vessels which require the application of hemostatic forceps immediately, since many of these will be entirely controlled by pressure from the instrument extending over a few minutes. In many operations it is advisable, before making the incision, to control completely the circulation of the part. Where this is not necessary, it should not be done, as the elastic constriction which is sufficient to give circulatory control may produce injury, and some authorities claim that it is productive of reactionary bleeding.

Most surgeons at the present time recommend an absolutely dry technic, and wherever possible this is advisable, especially in clean wounds. This means that no irrigation of the wound is done at any time during the progress of the operation unless specially indicated, and that the sponges which are employed are used dry. I always practise this dry method as far as possible.

The use of a blood-pressure apparatus is recommended in certain serious operations; it gives a very clear indication as to the patient's condition, and warns the operator very early in case of shock. The technic of the blood-pressure apparatus is considered in Vol. I.

Drainage.—With the completion of the operation the question of drainage will arise. Formerly, practically all wounds, whether clean or infected, were drained; the reverse of this is true at the present day, drainage in clean wounds being but rarely employed. Where there is a large wound, however, or a great deal of fat in the wound, or where a dead space between the tissues cannot be avoided, a small gauze drain or a small drainage-tube is advisable for a few days. Where any portion of a capsule of a tumor or a cyst-wall is not removed, drainage is indicated. Abdominal drainage is considered elsewhere, and the various kinds of drains and their methods of employment are described in another portion of this section. (See Vol. III., p. 714.)

The Closure of the Wound.—As this subject is also dealt with in the section on Abdominal Technic (Vol. III., p. 717), it is only necessary here to speak of it in a general way. As far as practicable, as little tissue should be included in a suture as possible. Sutures passing through skin, muscular tissue, and fascia are to be avoided, as, in order to approximate the deeper structures, the suture must be drawn entirely too tight. Tight suturing is undoubtedly productive of a marked tendency to infection, as it cuts off to a considerable extent the blood-supply of the tissues, and thus reduces their resistance. There is no doubt that a comparatively clean wound, such as a lacerated wound of the scalp, which would otherwise heal by primary union, can be made to suppurate by tight suturing. All that nature requires is a gentle approximation of wound edges; more than this is detrimental. The present custom of closing wounds in layers has done much to reduce suppuration and increase the comfort of the patient. Care should be exercised to avoid the leaving of a dead space

between tissues, the occurrence of which is one of the arguments used against closure of wounds in layers. The superficial fascia is a structure which has not received the attention it deserves in the closure of wounds. If it is not included in the skin sutures, it should be approximated by a separate suture, as this does much to prevent the spreading of the skin-scar and disfigurement of the patient. Further points in regard to the use of sutures will be found under the head of Sutures and Ligatures in this section.

The skin may be approximated by Michel's metal clips, but in using them care should be taken not to produce too much pressure, as otherwise marked scarring will result. These clips require a special forceps for their application and removal. Fig. 226 shows the clips and the forceps.

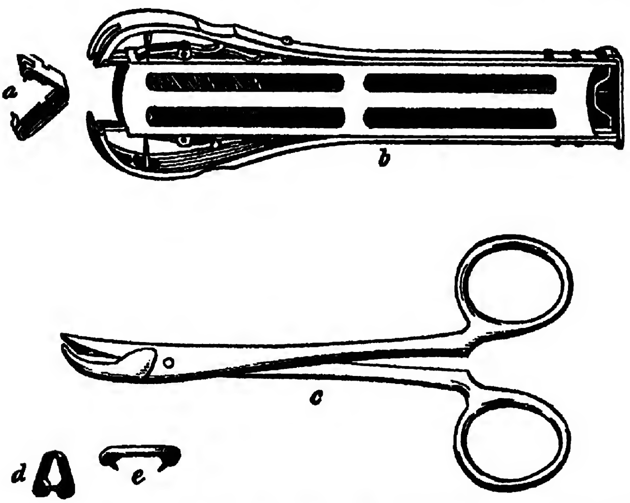

FIG. 226.—MICHEL'S CLAMPS, CLAMP APPLIER, AND FORCEPS FOR REMOVAL OF CLAMPS. (After Doyen.)

a, Michel's clamp; *b*, Doyen's automatic clamp applier "loaded" with a number of clamps; *c*, forceps for removal of clamps; *d*, shape of clamp when applied to the wound; *e*, clamp straightened out by the forceps for its removal.

Sterile adhesive plaster containing zinc oxid may be used for approximating the skin.

Synchronous and Multiple Operations.—Synchronous operations, especially in the case of amputation, are probably advisable, since they lessen the time that the patient is on the operating table and hence tend to lessen the subsequent shock. If the two operations cannot be done at the same time without the operators interfering with one another, then it is far better for all the work to be done by one operator. The question of multiple operations must be decided largely by the patient's condition. The tendency lately has been, especially in abdominal surgery, to resort to multiple operations, such as gastro-enterostomy, cholecystectomy, and appendectomy. Whether the surgeon is justified in doing a number of more or less dangerous operations at one time must be determined entirely by the patient's condition, the necessity for the operations, and the time required. Personally,

I am not inclined to be very radical in this regard, especially where more than one incision is required. As a rule, excepting where the operator is one of wide experience, it is better to deal with the more serious lesion first and postpone the treatment of the others. No absolute rule, however, can be laid down upon a subject such as this.

Dressing of the Wound.—Aside from sterility, the most important points in the application of a dressing are that it shall give support to the wound and comfort to the patient. There should be no unnecessary constriction of the part, nor should the bandages hold the part in an unnatural or constrained position: if they do, the patient is sure to be uncomfortable until the dressing is changed. The best dressing is made of dry sterile gauze. Some surgeons prefer to place some other material next to the wound, and at the Johns Hopkins Hospital silver- or tin-foil is used for this purpose. Where a raw surface is exposed to the dressing, it may be covered with strips of sterile rubber tissue with sufficient space left between them to allow the secretion from the wound surface to escape into the dressing. (For materials used for dressing the reader is referred to an earlier portion of this section.)

Redressing.—If the operation has been an aseptic one, if there is no drainage, and if the dressing has been properly applied at the time of operation, it should not be changed until the wound is entirely healed, or for the purpose of removing the stitches, which, however, is usually not done until about the seventh to the ninth day. The following are indications for a change of dressing before this time: an excessive amount of discharge; bleeding sufficient to extend to the outer portion of the dressing; displacement of the dressing, which permits exposure of the wound; continuous pain, which is referred to the wound, and symptoms of infection, such as a sharp rise of temperature accompanied by localized pain and tenderness. In many clean operations the infection which occurs is of a mild type, and is often indicated only by a moderate degree of fever. Where the temperature remains between 99° and 100° F. for several days after an operation the question of infection of the wound should be carefully weighed, and the dressing changed for the purpose of inspection.

POSTOPERATIVE TREATMENT.

Among the chief complaints after operation are pain, nausea, and thirst. The pain, of course, varies greatly according to the site of operation and the individual disposition. Probably abdominal operations produce more pain than others, but this may be only because of the aggravation of the discomfort caused by the movement of the diaphragm, especially such excessive actions of this muscle as take place in retching and coughing. One of the surprising things about postoperative pain is that it is not more marked in certain plastic operations, such as hernia, repair of the perineum, etc. In all of these, however, it can be made very severe by too tight constriction of the wound edges. Too much attention cannot be given by the surgeon to the prevention

of pain at the critical period when quiet and sleep do so much to aid a prompt convalescence. There was a time, not long since, when it was the rule of most surgeons to withhold pain-relieving drugs, such as morphin, after abdominal operations. To give a hypodermic of morphin in these cases was thought to be a great mistake, but now we have learned that when properly employed in the postoperative treatment it is a great boon both to the patient and to the surgeon. All the bad effects formerly attributed to this drug, such as the production of flatus, bad effect on the kidneys, etc., we seem now to have forgotten, or at least we have learned that it was our own faulty technic which produced much of the trouble attributed to the morphin. It was usually infection and not the drug that caused the trouble. It has been my invariable custom in abdominal operations to give a hypodermic of morphin, $\frac{1}{4}$ grain, and atropin, $\frac{1}{150}$ grain, before the patient has recovered consciousness, and I have never in a single case observed any bad effect follow this method. In many cases this hypodermic is given fifteen or twenty minutes before the anesthetic is started, but it is always given before the patient regains consciousness. The result is that the patient passes from the sleep of the anesthetic to the morphin sleep, gets comfortably over the most distressing hours after operation,—those first few when ether is being eliminated by the lungs in large quantities and nausea and vomiting are common,—and never knows that morphin has been given. The idea that morphin employed in this way is productive of vomiting is a mistake, except it may be in a few patients with an idiosyncrasy to morphin. My experience in using morphin and atropin in abdominal cases showed vomiting to be so much less than in other operations in which it is not employed that I now use it in practically every operation of magnitude or long duration or those which I expect to be followed by much pain. It is seldom necessary to give a second dose, and this I try particularly to avoid, for it is better not to let the patient learn the comfort of morphin. Repeated small doses after operation do not appeal to me, because the patient is apt to become dependent upon it. When the single full dose is given before the close of the anesthesia, if not disturbed, the patient will often sleep for from one to three hours and remain quiet for a much longer period. It is very important in this postoperative stage, and especially when the patient is recovering from the anesthetic, to keep sympathetic relatives and friends out of the room. Their presence often excites and greatly disturbs the patient.

Pain developing some hours after an operation is not to be treated by the administration of an anodyne, but its cause should be carefully sought and removed. A careful and considerate nurse can do much to relieve such pain. Oftentimes the simple change of posture, the cutting of a tight bandage, the relief of pressure on some bony prominence, straightening out the clothing, and such little attentions will give relief. I have seen a patient kept awake all night by pressure on the heel after fracture of the leg, and by pressure on the internal condyle by an internal angular splint. Pain under such circumstances is

absolutely unnecessary, and its possible cause should always be considered. I have known a safety-pin to be passed through the patient's skin in fixing a bandage and to remain in this position for days. Therefore, instead of putting down the patient's complaint of pain to nervousness or to want of pluck, we should always make sure that there is not some actual cause for the complaint.

Nausea and vomiting are not nearly so troublesome after operations as they once were. This partly is due to the improved methods of administering our anesthetics, and it can be obviated to some extent by making the quantity of anesthetic employed as small as possible. The amount of ether and chloroform administered has much to do with the continued vomiting after operation, and it can easily be reduced by the judicious use of morphin and atropin administered either before or during the anesthesia, or by administering chlorid of ethyl or nitrous oxid before the ether or chloroform. It is my invariable custom to employ chlorid of ethyl first, and in this way the amount of ether is reduced nearly one-half. The less ether there is for the patient to eliminate, the less nausea and discomfort he will have, and the less likelihood of interference with the eliminating function of the kidneys. As I have indicated before, the use of morphin at the close of the operation before the patient regains consciousness will entirely obviate or greatly reduce vomiting. Inhalations of vinegar have long been employed to reduce nausea, and do seem to be productive of some good. So simple a means as elevation of the head will often reduce the sensation of nausea, and a draft of water will sometimes not only not increase the nausea, but will reduce it. When it is possible for the patient to be placed in the sitting position, nausea will frequently be relieved. This is particularly true after operations on the stomach itself. A drainage-tube placed in the abdominal cavity may produce continued reflex vomiting, which will cease on removal of the tube. In my own experience, troublesome vomiting is rare where a full dose of morphin is given before or during the operation.

Thirst, too, is a symptom which is much less troublesome now than formerly, where water was withheld for long periods after operation. The thirst can be largely relieved by giving large quantities of salt solution by the rectum. There are few operations, however, after which water cannot be given promptly by the mouth. If a patient is not nauseated, I allow him water within a few hours in quantities of an ounce. It has not been my experience that this is apt to start up vomiting. This early administration of water applies after abdominal operations as after others. The giving of a considerable quantity of water at regular intervals is preferable to the continual sucking of ice. Liquid food should be given as soon as the patient has a desire for it, or as soon as the nausea has passed away.

Confinement in one position, with the restriction of all movement after an operation, is extremely trying to a patient, and often results in insomnia and nervousness. Any movement that does not directly interfere with the healing process of the wound should be allowed.

It does not hurt a properly closed abdominal wound if the patient is early placed upon his side, or if the shoulders are elevated or the legs drawn up. When a patient is very anxious to change his position and you are sure this change will not be comfortable, it is not a bad plan to allow him to try the new position, when he will be convinced of his own error and more contented in the position he first occupied. Too much care cannot be given to obtaining a comfortable attitude in bed after an operation. Restraint in an unnatural position gives rise to the greatest restlessness and discomfort. This is well illustrated in the tight confinement of the arm to the chest after breast operations. The patient is much more comfortable, the wound heals better, and there is less restriction of subsequent motion of the shoulder if the arm is dressed at a right angle to the body.

It is sometimes desirable to keep the patient in a sitting posture, and various devices have been suggested for the comfortable support

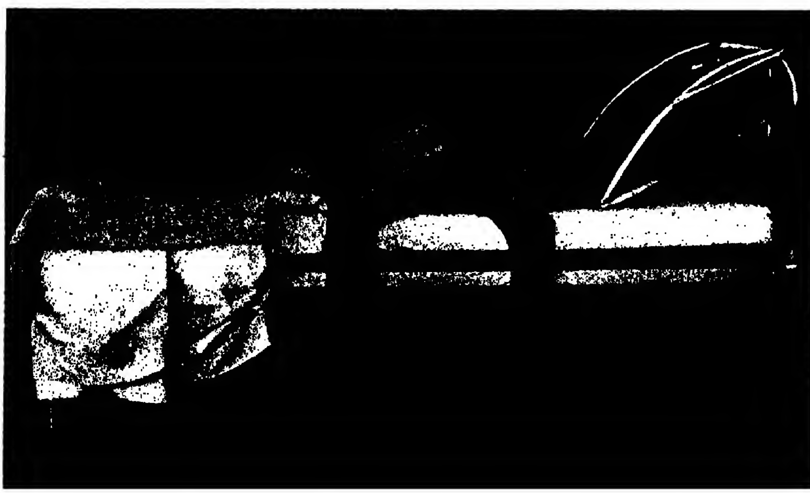

FIG. 227.—W. E. LEE'S SUPPORT FOR MAINTAINING THE SITTING POSTURE.

of the patient in this position. Figs. 227 and 228 show a frame devised by Dr. W. E. Lee, of the Pennsylvania Hospital, which is placed under the mattress, and which I have used for a number of years in cases of general peritonitis with the greatest satisfaction. The ordinary bed-rest is entirely inadequate in these cases.

The question of the best time to open the bowels after operation is one about which surgeons will probably always differ. Formerly, it was the custom of most operators to give some laxative, usually calomel, on the day following the operation, especially in abdominal cases. This was due to the fact that it was thought that an early movement of the bowels usually meant that no infection of the peritoneum had occurred, or that such infection was not extending. The mere movement of the bowels, however, is no criterion under such circumstances, and it is far better to let the intestine rest quietly after an operation

than to stir up painful peristalsis by the means of laxatives. This, of course, applies to cases in which a proper preparation for the operation has been made. A movement by a glycerin suppository or an oil or soapsuds enema is much more comfortable to the patient and less disturbing than a purgative. If nothing but liquid food is given for two or three days after operation, the third day is sufficiently early to open the bowels.

Inability to empty the bladder is of common occurrence in the postoperative period, and resort to the catheter is often necessary. To resort to catheterization when the bladder is not painfully distended is a mistake, and it is far better to have the patient empty the bladder himself than to pass the catheter. Some surgeons even go so far as to allow the patient to get out of bed for this purpose, and where it is possible, I believe it to be good treatment. I avoid the use of the

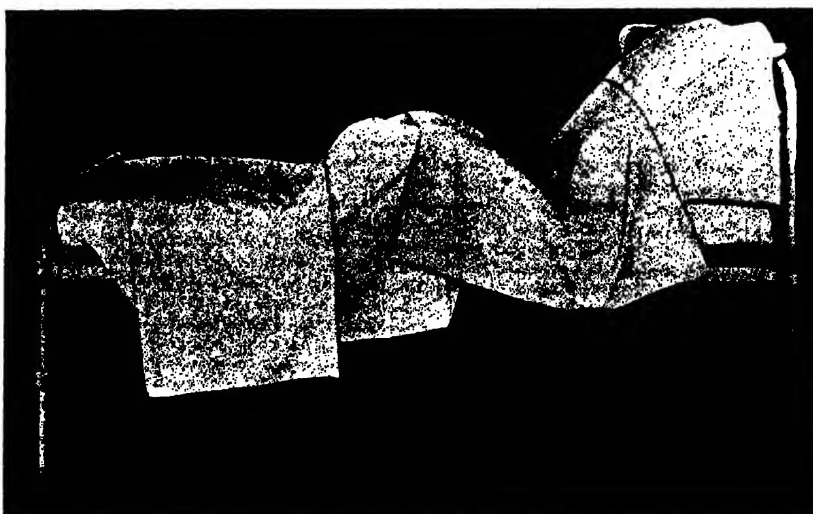

FIG. 228.—LEE'S SUPPORT ARRANGED FOR PATIENT.

catheter as much as possible. When the catheter is employed, the greatest care should be exercised, and the catheterization done by an experienced orderly or nurse, or, better still, especially in men, by the surgeon himself. Even under the best circumstances infections of the urethra and bladder occur, and it is the surgeon's duty to see that all necessary aseptic precautions are taken to avoid these unfortunate complications. No nurse or orderly should ever be allowed to use a metal instrument. Catheterization in children is to be particularly avoided, as injury of the male urethra in childhood is easily inflicted. In children I would much prefer to have the patient get out of bed to have a catheter used.

The time at which a patient is allowed to get out of bed varies with the operation which has been performed. A few rules, however, can easily be laid down. In the first place, old people should be got out of

bed as soon after operation as possible. The advantage of this is easily shown in the present-day results from prostatectomy, where the patient is got out of bed on the second or third day. In abdominal operations on old people a change of posture and early transference from bed to couch or chair is very important. There has been a marked tendency during recent years to shorten the period which a patient spends in bed after an abdominal operation. After simple appendectomies many surgeons allow their patients to get out of bed on the following day. I have not been able to bring myself quite to this point, but I am constantly shortening the period. In clean cases where the abdominal wound is accurately closed and no muscle cut across its fibers, I get the patient out of bed on about the eighth or ninth day, with the abdomen well supported by a binder, and allow moving about on the tenth or eleventh day. In this particular I think the individual disposition of the patient must be taken carefully into account. There are many patients who are benefited by a longer rest in bed, whereas to others, such as old people, and those who are inclined to magnify their ailments, a prolonged rest may be harmful.

Elements which exercise considerable influence on the postoperative progress of patients are good air, sunlight, and good food. Every hospital should be properly ventilated, and as much sunlight admitted to the wards as possible. If a roof-garden or sun-parlor is possible, it is an adjunct of no little value in the postoperative treatment.

Postoperative Complications.—Two of the most important complications are shock and hemorrhage. Both of these conditions and their treatment have been fully considered in other portions of this work. The same is true of pulmonary embolism, which occurs occasionally after the simplest and cleanest operation. Apoplexy sometimes occurs during the progress of an operation or during the postoperative period. No doubt if more autopsies were made on patients dying from unaccountable causes on the operating table, it would be discovered that apoplexy was occasionally responsible. Rupture of unsuspected aneurisms of the aorta has occurred on the operating table and during the postoperative period. Suppression of urine is far less frequent than it formerly was, and when it does occur, it is a most distressing and dangerous complication. The amount of urine secreted after operation should be carefully measured by the nurse or attendant, so that suppression may be detected as early as possible. When this condition does arise, it calls for active treatment, such as the administration of diuretics, sweats, and sometimes the use of diluted salt solution administered by hypodermoclysis or intravenous injection. Of course, the surgeon will be careful not to confound retention of urine with its suppression. Obstruction of the bowels from various causes is a complication after abdominal operations which has been carefully and thoroughly dealt with elsewhere. Infection of the wound is ordinarily of rare occurrence unless the infection has existed prior to the performance of the operation. The most important element in the treatment of this condition consists in thorough drainage of the wound.

Fat embolism is probably frequently the cause of death, and is often mistaken for shock.

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CHAPTER LXXIII.

LIGATION OF ARTERIES IN CONTINUITY.

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General Considerations.—The ligation of an artery signifies the constriction of the artery by means of a ligature for the purpose of controlling the circulation in that vessel.

A ligation may be "terminal," where the cut end of an artery is tied; "in continuity," where tied in its unbroken course; "single," where but one ligation is used; "double," where two are applied (as in dividing a vessel between ligatures); "immediate," where applied directly to the artery proper; "intermediate," where the ligature passes around more or less connective or other tissue surrounding the artery (as in ligation for parenchymatous hemorrhage); "permanent," where applied to remain; or "temporary," where applied for the arrest of circulation for a brief period.

The **indications** for ligation of arteries are: wounds; aneurisms; hemorrhage from the main trunk near site of ligation, or from either the main trunk or one of its branches at a distance from the site of ligation; rupture of vessels; angeiomata; to control hemorrhage in operations distal to site of ligation; to lessen the nutrition of inoperable tumors; to cause the atrophy of an organ by diminishing its blood supply.

Preparation.—No general (constitutional) preparation is necessary for the smaller ligations. In the case of ligation of the larger arteries the systemic state of the patient should be looked after as in other major operations. Locally, the usual antiseptic preparation of the part should be carried out, the patient coming to the table with the site of operation in an aseptic dressing.

The patient should rest upon a table of proper height, and so placed as to bring the involved artery most conveniently and advantageously before the surgeon. The surgeon stands where he can best manipulate, which is generally on the side of the operation, and usually cuts downward on the right and upward on the left. The assistant generally stands opposite the surgeon and exposes the field of operation by retraction or assists in the steps of the ligation. The position of patient, surgeon, and assistant will vary according to the artery operated upon, and will be given in the individual operations.

The *instruments* generally used are the following: Esmarch bandage and tourniquet; scalpels, heavy and light; scissors, straight and curved,

sharp-pointed and blunt; forceps, dissecting and toothed; hemostatic forceps; grooved director; tenacula; retractors, various sizes and shapes; aneurism needles, large and small, straight and laterally curved; ligature carrier; ligaturing and suturing material, viz.: needles, straight and curved, surgeon's and Hagedorn; needle-holder; wound-hooks; drainage materials (for special emergencies); special small needles, fine silk and needle-holder for repairing wounds of veins; means for illuminating deep wounds.

The *ligature materials* in general use are the following: plain catgut; chromicized catgut; kangaroo tendon; ox aorta; silk, plain and floss. For the closure of skin wounds at the termination of the operation silkworm-gut or silk sutures. For the ligation of smaller arteries, plain catgut. For medium arteries, chromic catgut. For the largest arteries, kangaroo tendon (flat); ox aorta (flat); chromic catgut; soft floss silk.

For the satisfactory carrying out of the ligation a systematic course should be followed in all cases, the proper steps of which are given below, in order:

Preliminary control of the circulation is indicated in some ligations. In ligating the arteries of the head, neck, and trunk no attempt is usually made to control the circulation by any means of pressure. In the limbs, also, it is rarely absolutely necessary. But where its use is preferred—and the satisfaction of operating in a dry field is unquestionable—the limb is first elevated, the soft parts massaged toward the trunk, and the tourniquet of Esmarch (without the previous use of the Esmarch rubber bandage) is applied around the limb, as high up as indicated. The sacrifice of the guiding pulsation (necessitated by the use of any form of constrictor) is counterbalanced by the dryness of the field, especially in prolonged and difficult operations.

The line of the artery is determined in advance of any operative step, and is based upon a knowledge of the anatomy of the part. A knowledge of the chief variations in the course of the arteries should also be possessed. Acquaintance with the line of the special artery is an absolute prerequisite, a correct line, properly followed, leading directly and expeditiously to the goal of the operation; an incorrect line, once taken, often plunging the operator into unnecessary difficulties from the start, frequently requiring loss of time, retracing of steps, unnecessary injury to the structures, and the regaining of the right path finally after considerable and humiliating bungling. This line of the artery may be previously marked out upon the body with a sterilized dermographic pencil (or nitrate of silver stain), but such marking is generally unnecessary. The line of the artery is frequently modified by the position of the limb and in such cases a constant position should be understood to apply in speaking of such arteries (for instance, the line of the brachial artery is one thing if the arm be lying out supine at a right angle to the body, and another if resting on its inner border, parallel with the thorax). On the other hand, no change in the position of the foot causes a change in the line of the dorsalis pedis. The line

of an artery often coincides so nearly with muscular or tendinous landmarks that these landmarks are frequently given instead of the line itself. For instance, one may speak of ligating the brachial artery by incising along a line extending from the junction of the anterior and middle thirds of the outer axillary boundary, to the middle of the bend of the elbow, the arm being at a right angle to the body and on its extensor surface; or one may also speak of ligating this artery by incising along the inner border of the coracobrachialis muscle above and the biceps below. It is well to know both the commonly accepted "line" and the natural muscular or other markings. The former is usually the more accurate guide to the vessel, especially in the early stage of the operation (for instance, in the above case the brachial artery is often considerably overlapped by the biceps in a well-developed subject), though the latter are the natural boundaries which generally have to be encountered and manipulated before finally reaching the artery. In other cases the line bears no relation whatever to external muscular or tendinous elevations or furrows and in such cases the line alone has to be blindly followed in the early part of the operation as a guide to the course of the artery (as in the case of the upper portion of the ulnar artery).

Incision.—The incision for the exposure of the artery is the first step in the technic of the operation, upon the proper placing of which the ease of the subsequent steps largely depends.

Position and Direction of the Incision.—In the great majority of cases the line of incision coincides with the line of the artery from the beginning to the end of the operation, superficially and in the deeper layers (as in the ligation of the popliteal artery in the middle of the popliteal space), and should be so placed as to have its center over the site of ligation. In other cases the line of incision will follow a muscular marking, even if at a slight variance with the recognized "line of artery" (*e. g.*, in ligating the common carotid above the omohyoid the incision is made parallel with the inner margin of the sternomastoid, which in muscular and well-developed necks is known to overlap and to lie slightly to the inner side of the artery. In other cases the incision follows neither the line of the artery nor the muscular marking, but lies in a course parallel with both line of artery and muscular fibers, and is so placed as to reach the vessel most advantageously and with least damage to neighboring structures (*e. g.*, ligation of the posterior tibial artery in the middle of the leg). In other cases the incision may coincide with the line of artery, but cross an overlying muscle at a right angle (*e. g.*, ligation of the lingual artery beneath the hyoglossus muscle). In still other cases the incision may cross the course of the artery at a right angle (*e. g.*, ligation of the external iliac extraperitoneally by an incision parallel with Poupart's ligament).

(1) *Superficial Incision.*—Having chosen the line of incision as free from superficial vessels and nerves as circumstances permit, steady the area of incision by means of the left thumb and forefinger, which, by their separation, put the parts under slight tension and give room for

the knife cut between them. Grasp the scalpel in the "pen position" for finer, more limited cuts, and in the "dinner-knife position" for heavier, longer cuts. Enter the point of the scalpel at a right angle to the skin surface, traverse the line of incision with the knife-handle at about 45 degrees, and withdraw the knife with the point of the blade again at a right angle with the surface, thereby cutting to equal depth throughout. This incision should pass through skin and superficial fascia and, while not unnecessarily long, should be amply long enough to enable subsequent manipulations to be carried on without injury to the structures. The length of the incision should rather be determined by the depth of the artery and the nature of the parts to be encountered than by any attempt to remember an arbitrary length of incision for each artery. The deep fascia is similarly divided in the original line, avoiding, where possible, superficial vessels and especially nerves.

(2) *Deep Incision.*—Having passed through all overlying fascia in the superficial incision, the muscle and tendinous landmarks now come to both sight and touch. Generally no further cutting is necessary, the rest of the approach and exposure of the artery being accomplished by blunt dissection. In by far the majority of cases arteries are henceforth reached by following down between muscular planes, it being very rare that muscle-fibers are separated and rarer still that muscles are cut transversely. At this stage of the operation the muscular or tendinous boundaries are recognized and followed to the known position of the artery, the intermuscular planes being separated by the handle of the scalpel rather than by the blade, and this separation being carried out to correspond with the length of the superficial wound. The three best means of recognizing intermuscular planes in the order of their reliability are: the sense of touch of the tip of the left index-finger (which flexion of the limb may assist); the following down of the intermuscular branches of the artery; the white fascial or yellow fatty so-called "line" in the intermuscular spaces. It is of great importance to recognize the proper intermuscular space at the start, as once in a wrong intermuscular interval, one may wander on indefinitely, completely off the track, missing the artery and doing much damage to the parts. Good retraction should be freely used at this stage and muscles and tendons should be drawn to their proper sides (flexing the limb often aiding considerably in this retraction). Important vessels, nerves, and other structures should be guarded during this separation of the parts, and, when in the way, should be displaced to the more convenient side of the operation field, always remembering that nerves are the most important structures to be safeguarded in the great majority of cases. If an Esmarch have not been used, the wound is kept comparatively dry by frequent sponging of the field with dry gauze wipes.

The **exposure of the artery** now follows. Having gotten down to the region of muscles and tendons, these should be clearly identified and the artery sought by its known relation to these structures. The muscles and tendons are the rallying points in the depth of the wound.

Three structures outwardly more or less similar in appearance and often in sensation are to be distinguished: arteries are recognized by their known course; their pulsation, where no proximal constriction is used; their swelling proximally when compressed distally (where no constrictor is used); their firm, round, resisting, elastic, cord-like feeling; their peculiar sensation when compressed between the fingers, presenting a central depression and two lateral elevated ridges; their thicker walls; their rubber-tube-like feeling when touched, and tendency to glide from beneath the fingers; the force required to compress them; their regular outline; their pinkish or pinkish-yellow color. Of these means of recognition, pulsation is the conclusive test, provided there can be eliminated all possibility of error caused by pulsation transmitted through contact (as a vein or a nerve made to rise and fall by an artery beating beneath or to one side of it). Veins are recognized by not pulsating (where no Esmarch is used); by having thinner coats; by swelling toward the periphery when compressed centrally (no constrictor being used); by being softer and less resisting to the touch; by the flat, ribbon-like feeling throughout their whole width when compressed between the fingers; by their purplish color; by their wavy, irregular contour; by their accompanying the arteries in many regions in pairs or companion veins; by their larger size than the corresponding arteries; by the ease with which they are compressed. It may be mentioned here, in connection with the companion veins, that two venæ comites are to be found accompanying all arteries below the axilla; all arteries below the knee; most of the small and medium-sized arteries of the trunk; and that the arteries of the head and neck are accompanied by single veins. These veins generally run on either side of the artery, communicating across the artery at frequent intervals, generally lying in front of and behind the artery when the intermuscular plane enclosing the artery lies anteroposteriorly, and usually lying to the right and left of the artery when the intermuscular plane runs transversely. Nerves are distinguished by their known position; their white color; their round contour; unyielding consistency and non-compressibility; their appearance of being made up of parallel bundles; their swelling neither proximally, like arteries, nor peripherally, like veins, when compressed (no constrictor being used).

Opening the sheath next follows. Having identified this structure and brought it well within the field, its wall is to be opened and the contained artery exposed for the purpose of clearing a path for the aneurism needle (Fig. 230). Only the main vessels have a distinct sheath of connective tissue, and the larger the artery the more distinct the sheath. In some cases the accompanying vein and nerve are included in a common sheath, together with the artery, the sheath being composed of more of less condensed connective tissue. The smaller arteries are surrounded by a less distinct layer of areolar tissue, generally not demonstrable as a sheath. The sheath should be opened at least 1.3 cm. (½ in.) from any branch. With a pair of finely pointed forceps pick up the sheath where it is desired to pass the ligature, and

in such a way as to raise the sheath in a fold parallel with the long axis of the vessel (Fig. 229, B). Let the forceps pick up the sheath upon its anterior aspect, but slightly to one side of the median longitudinal line, thereby leaving space to incise the sheath exactly in the middle line. After grasping the sheath shift the forceps gently up and down to see that the sheath held in the bite of the forceps glides over the contained vessel, proving thereby that no part of the artery itself is picked up. This longitudinal fold of the sheath, while held by the forceps and lifted up from the artery, is incised in the long axis of the artery for a distance of about 6 to 8 mm. ($\frac{1}{4}$ to $\frac{1}{3}$ inch) (the shorter the distance of separation of the sheath the better to preserve the vasa vasorum), the flat surface of the knife being turned to the artery (Fig. 229, C). As soon as the incision is made in the sheath, a gap appears between

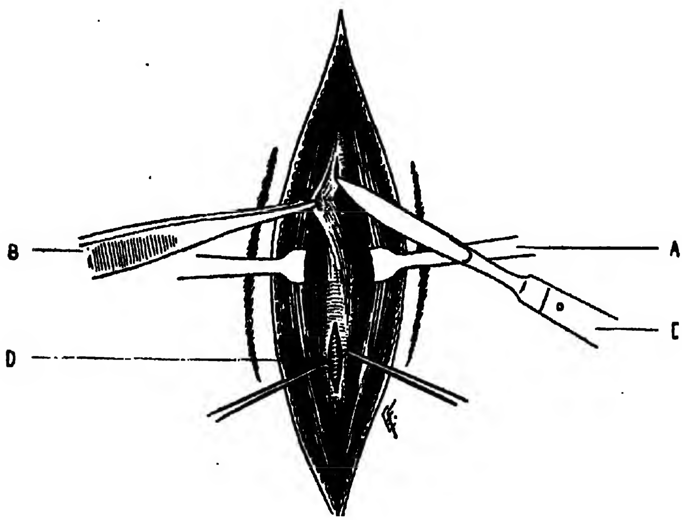

FIG. 229.—LIGATION OF AN ARTERY: OPENING THE SHEATH.
A, Retraction of adjacent muscles; B, toothed forceps raising sheath of artery in a longitudinal fold; C, incising sheath in long axis of artery; D, artery visible through incised sheath.

the wall of the artery and the wall of the sheath (Fig. 229, D). The hold of the forceps upon the wall of the sheath should be retained, not being relaxed after once grasping the fold of sheath. In ligating smaller arteries which have no well-defined sheath the vessel is simply freed of all visible connective tissue. (This axial division of the sheath of the artery is preferable to the transverse division so often advised.)

The **artery is now cleared** for the passage of the ligature. A path for the passage of the ligature between the outer wall of the artery and the inner wall of the sheath is now to be made, and the best instrument with which to make it is the dull, flat end of a curved aneurism needle. Having retained the original hold of the forceps upon the sheath (Fig. 230, B), insinuate the end of the needle between this wall of the sheath and the artery, and while drawing this lip of the sheath gently away from

the artery carefully work the point of the needle around one-half of the circumference of the artery, in the connective-tissue plane between artery and sheath, by a combination of forward movement on the part of the tip of the needle, with a side-to-side movement on the part of the lateral margins of the curved tip over a distance of from 6 to 8 mm. —¼ to ⅓ inch (Fig. 230, C). Having thus cleared a path around half the vessel and still holding the tip of the needle in the path already cleared, the forceps for the first time relinquish their hold on the lip of the sheath originally grasped, and grasps the opposite lip of the sheath and similarly draws this part of the sheath away from the artery (Fig. 230, D), at the same time also similarly working the point of the needle onward and from side to side, until it clears a path completely around the

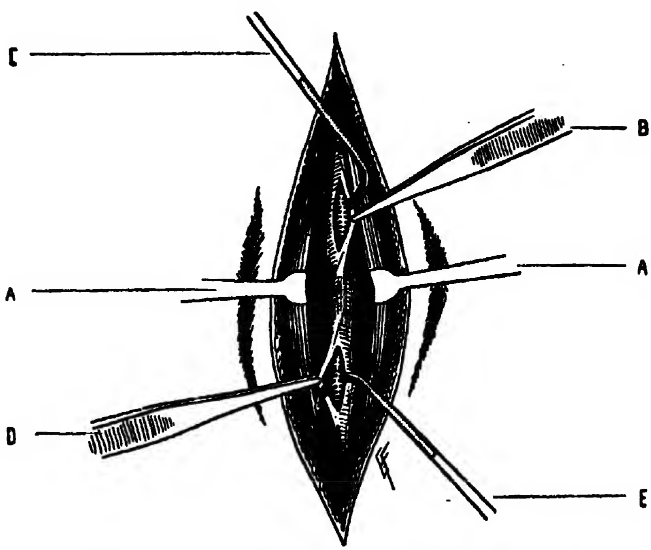

Fig. 230.—Ligation of an Artery: Clearing the Artery.

A, A, Retraction of adjacent muscles; B, forceps grasping nearer lip of sheath; C, aneurism needle clearing artery in its passage between sheath and vessel; D, forceps grasping further lip of sheath; E, aneurism needle emerging between artery and further lip of sheath.

artery and appears between the vessel and the further lip of the sheath (Fig. 230, E). Throughout this entire maneuver the handle of the needle is held approximately at a right angle to the vessel, and the tip of the needle hugs the wall of the artery, especially working under its deepest part, particularly where a common sheath contains other structures, and thereby is prevented from penetrating the sheath and injuring the vessels, nerves, or viscera beyond.

The ligature is next passed. Once a passage has been cleared between the artery and sheath, the aneurism needle readily traverses it, so that as soon as the needle has appeared on the further side of the artery it is withdrawn. The needle is now threaded and carefully passed between the vessel and sheath, through the previously cleared way, following precisely the same course and carrying out the same

steps, first opening the entrance to the passage by drawing the sheath away with forceps, then hugging the vessel in making the circuit, and finally emerging on the opposite side between the vessel and the further lip of the sheath, which the forceps have now grasped and drawn away (Fig. 231). An aneurism needle may be passed with a fine silk ligature-loop as a carrier, and through this "carrier" the proper ligature may be threaded and drawn back. There is no fixed rule for the direction in which the needle should be passed in each case; the rule should be that the needle is to be passed from the more important structures toward

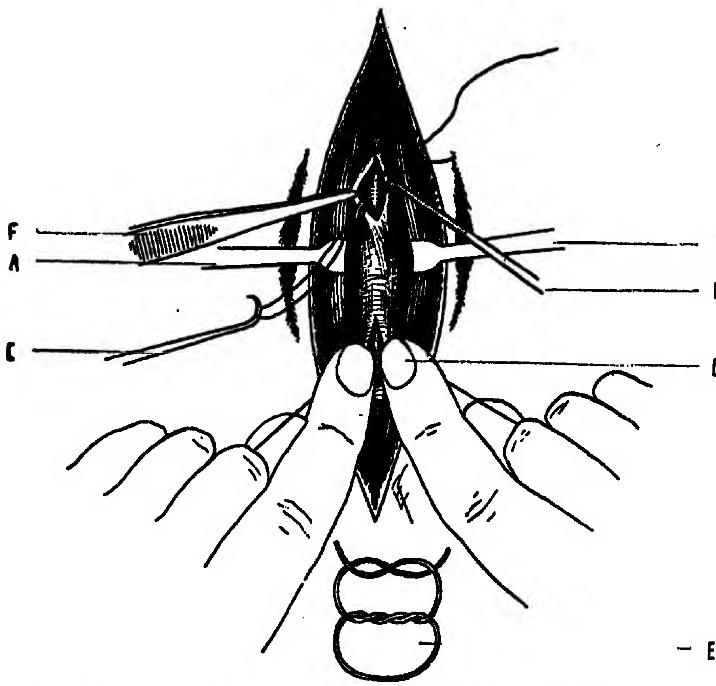

FIG. 231.—LIGATION OF AN ARTERY. (Passing the ligature and tying the knot.)
A, A, Retraction of neighboring parts; B, aneurism needle carrying ligature beneath artery; C, tenaculum drawing one end of ligature under artery, while aneurism needle is being withdrawn; D, tying the knot; F, retracting lip of sheath.

FIG. 232.—KNOT USED IN LIGATING MEDIUM AND LARGE ARTERIES.
E, Two turns of a friction-knot followed by a reef-knot, constituting a surgeon's knot.

the least important, or from the structures more difficult to avoid toward those more easily avoided. Therefore the needle may enter the sheath in the reverse order to that in which it has been freed from the artery, or vice versa, as seems safest and easiest. Having passed the needle completely around the vessel, until its threaded eye protrudes on the opposite side, grasp one of the threads of the looped ligature with forceps or tenaculum and, while thus held, carefully withdraw the needle, following the curve of the artery (Fig. 231, B, C). Thus a single thread is left beneath the vessel, an end coming out between the artery and sheath on either side. Some surgeons pass the needle unthreaded

and thread the eye on the opposite side, then, holding one arm of the ligature with forceps, withdraw the needle, with the same result. There is no objection to this method in simple cases where the artery is accessible and the threading easily done with the needle *in situ* (as in the lower third of the radial), but it should not be attempted in a region where the exposure is difficult (as in the retroperitoneal ligation of the common iliac). Such an instrument as the Cleaveland needle (ligature carrier) is preferred to the common aneurism needle by some, the instrument, being passed under the artery empty, grasps the ligature on the opposite side and draws back one end under the vessel. In arteries too small to have sheaths the ligature is simply carried under and around the artery, which has been freed of all connective tissue, the general method being the same as just described.

Tying the Knot.—The largest arteries are most safely and satisfactorily tied with the "stay-knot" of Ballance and Edmunds. The stay-knot of these surgeons is made by conducting two or more bundles of soft floss silk or two or more pieces of kangaroo tendon, catgut, silkworm-gut, or plain silk around the artery, parallel with each other and side by side; the first hitch of a reef-knot is then tied in each bundle, so that two or more knots lie side by side, the force to tie them having been sufficient to closely approximate the inner and middle coats of the artery and completely stop the flow, but without rupturing these coats (Fig. 233, A, and Fig. 234). A friction-knot is even safer than the first hitch of a reef-knot as the preliminary step, especially in tying the larger vessels. After tying these at first lightly, they are both taken up together and gently tightened simultaneously. The two or more ends of the bundles are then taken up on the one side and the two or more ends of the other bundles on the opposite side, the several bundles on each side now being regarded as one, and these two bundles are tied in a single knot, after the manner of the second step of a reef-knot (Fig. 233, B). Thus a knot is formed, the first part of which will not slip while the second is being tied (which is apt to be the case in large arteries, especially if they be pulsating at the time, thus allowing the establishment of a small stream of blood). By this method a broad compression and approximation of the arterial coats will be accomplished, which will add strength to the site of ligation against secondary

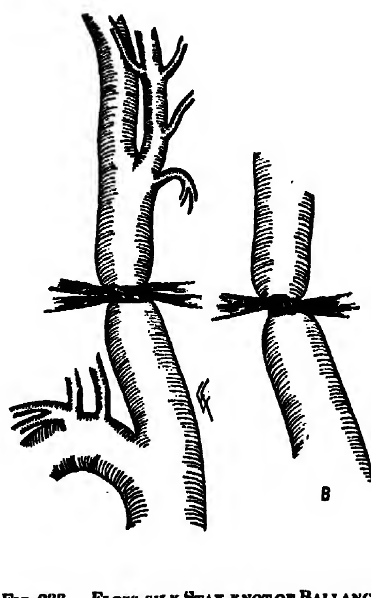

FIG. 233.—FLOSS-SILK STAY-KNOT OF BALLANCE AND EDMUNDS.

A, First stage; B, second stage.

hemorrhage. This simple approximation is sufficient to excite endothelial proliferation and union of the opposed surfaces. It is hard to draw such a ligature tight enough to rupture the inner coats. An artery with its two inner coats ruptured by ligation has only the strength of its outer coat to withstand the strain of the circulation until the secondary phenomena take place, which permanently strengthen the site, prior to which secondary hemorrhage may occur. Several parallel strands of smaller size chromic catgut led under the artery by a carrier are sometimes used, thus securing width for the ligature and the consequent distribution of pressure. All medium-sized arteries should be tied with a surgeon's knot (a friction-knot followed by the second step of the reef-knot) (Fig. 232, E). All small arteries are safely tied with the reef-knot alone. In making tension upon the ends of the ligature special care should be taken not to lift the artery out of its sheath. To avoid this the tips of the right and left forefingers should come together, end to end, directly upon the knot in the act of being tied, and the tightening should be done by putting the terminal and middle knuckles of the index-fingers in apposition, back to back, and using them as

FIG. 234.—THE STAY-KNOT OF BALLANCE AND EDMUNDS; SHOWING THE FIRST STEP OF TYING THREE KANGAROO-TENDON LIGATURES.

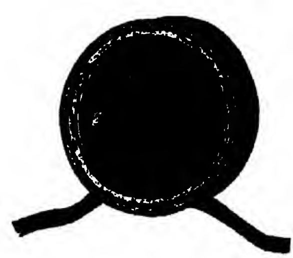

FIG. 235.—SHOWING THE PLEATING OF THE COATS OF A LIGATED ARTERY IN CROSS-SECTION. (Modified from Ballance and Edmunds.)

fulcra (Fig. 231, D). The thumbs may be similarly used instead of the forefingers. It is a disputed point as to how much tension should be used in tightening the ligature. It may be said that it is best to tighten the ligature upon all large vessels sufficiently thoroughly to approximate their inner wall in pleats, thereby completely closing the lumen without rupturing the two inner coats (Fig. 235). The same holds true of all diseased vessels, independently of their size. All medium vessels may be similarly ligated. The smaller arteries generally have their ligatures tightened sufficiently to rupture their inner and middle coats. A tightening almost sufficient to sever all coats, especially when using silk, is distinctly to be avoided. Secondary hemorrhage seems less frequent and the strength of the vessel greater when the vessels are only constricted enough to closely approximate the two inner coats without

causing their rupture. All knots should be cut comparatively short. A round ligature tightly drawn will rupture the inner coats. A broad ligature will do so far less readily.

The Closure of the Wounds.—Where a large, well-marked sheath has been opened in exposing the artery, although not absolutely necessary, it is well to unite the edges of the sheath by one or two fine catgut sutures. Where any muscle tissue has been incised in order to reach the artery it is usually best to repair the divided muscle tissue by a catgut suture passed through the lips of the muscle wound, which suture becomes buried in the final steps of the operation. Where deep intermuscular planes have been opened up and dead spaces are apt to be left, it is advisable to put in a few buried catgut sutures through the muscle tissue, drawing together the muscles into their normal intermuscular cleavage line. Where no muscle has been wounded, and in the final step of those cases where muscle has been incised and sutured, complete closure of the wound is accomplished by a line of interrupted silkworm-gut sutures, the suturing being materially aided by putting the wound on the stretch by a wound-hook in either end (Fig. 236). No form of drainage is used in clean cases. A simple gauze and cotton dressing, held in place by a bandage, completes the dressing.

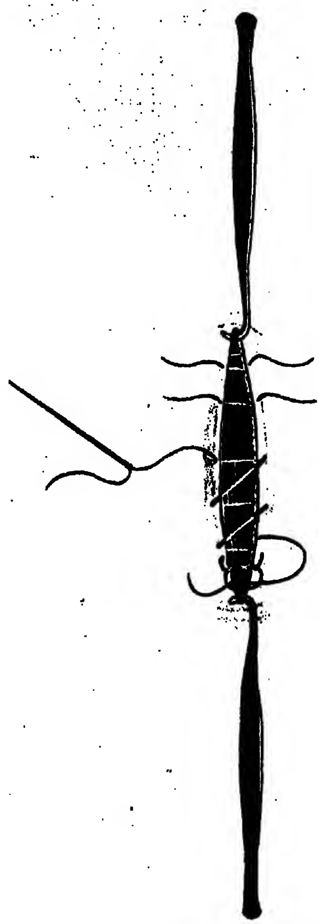

FIG. 236.—ILLUSTRATING THE MANNER OF SUTURING THE WOUND, THE EDGES OF WHICH ARE PUT UPON THE STRETCH BY WOUND-HOOKS AT EITHER END.
Interrupted sutures are shown at one end, and continuous suturing at the other.

The **after-treatment** is simple in the ligation of the smaller arteries. Where a large artery is ligated a splint should be incorporated in the dressing where feasible, in order to control all movement of this part. In the case of the main artery of the limb, the limb should be incased in cotton, and artificial warmth should be applied in addition until the new circulation is established. The limb is elevated in bed to favor venous return. The skin sutures are removed from the fifth to the seventh day, according to circumstances. A rest in bed of from two to four weeks is required in the ligation of the larger arteries.

The local results of ligation consist of the obliteration of the artery at the site of ligation and of the establishment of a new (collateral) circulation.

Fig. 237.—Incisions for Ligation of Chief Arteries of Head and Neck.

operation); E, same, by splitting manubrium; F, common carotid, above omohyoid; G, same, below omohyoid; H, external carotid, below digastric; I, same, above digastric; J, thyroid, at origin; K, lingual, at origin; L, lingual, beneath hyoglossus; M, facial, over inferior maxilla; N, occipital, behind mastoid process; O, temporal, just above zygoma; P, trunk of middle meningeal, by trephine opening exposed by curved oblique incision (lower of two trephine openings); Q, anterior branch of middle meningeal, by trephine opening exposed by horseshoe incision (higher of two trephine openings); R, posterior branch of middle meningeal, by trephine opening exposed by horseshoe incision; S, internal carotid, near origin; T, third part of subclavian; U, transversalis colli and suprascapular, at outer margin of sternomastoid; V, internal mammary, in second intercostal space; W, first part of axillary, by curved transverse incision below clavicle.

The chief dangers in the ligation of arteries are secondary hemorrhage, gangrene, and infection.

The following observations may be made in conclusion: (*a*) Where it is difficult or impossible to separate one or more veins from the artery, the artery and vein or veins may be included in the one ligature. (*b*) Especial care should be taken to avoid the inclusion of the smallest nerve in the ligature. (*c*) When a large vein is wounded, the wound should be at once closed by lateral ligature or by suturing, preferably the former. If this be not feasible, the vein should be ligated. All medium and small veins should be ligated if wounded. If the ligation of the artery can be accomplished without the likelihood of again wounding the vein, it should be completed at the original site. If there be danger of further complication, a new site should be chosen just above or below the one originally selected. (*d*) It is held by some that secondary hemorrhage is less likely if an artery be ligated in two places, from 2.5 to 5 cm. (1–2 inches) apart, and then divided between these two ligatures, allowing each end to retract, upon the principle that the arteries of the body are constantly under longitudinal tension and, when ligated in continuity (especially where the inner coats are severed), there are present the conditions calculated to predispose to secondary hemorrhage. Practical experience seems to have borne out the claim of the double ligature with division, but the operation is not always feasible, especially in the deeper, larger vessels. (*e*) All ligature material should be made thoroughly pliable before being used.

LIGATION OF SPECIAL ARTERIES.

Ligation of the Innominate Artery.—The innominate is ligated for aneurism of the right carotid and subclavian, and of the innominate itself.

Several methods of exposing the artery are in use, of which those given below are the chief. Comparatively speaking, the choice of approach would be given to non-division of muscles, with retraction—the oblique incision thus being preferable to the angular one—where these incisions promise sufficient room for manipulation. Where more room is necessary, especially from abnormal displacement of the parts (as from aneurism), the angular incision or the methods of partial resection give more space for the safe carrying-out of the necessary steps; and of these latter the method of partial resection of the right aspect of the manubrioclavicular region is applicable to cases where a more limited sacrifice of bone will suffice; and Bardenheuer's operation, or splitting of the manubrium, where the maximum space is required. The innominate has also been less satisfactorily ligated through a large trephine opening made in the manubrium sterni, after turning back a flap of soft parts.

The chief source of failure is secondary hemorrhage. The common carotid and vertebral arteries should, therefore, be also tied, being the main sources through which the recurrent flow occurs.

The free section of muscles leaves, by their retraction, a deep gap at the root of the neck for infection and slow filling up. As much re-

pairing of cut muscle tissue as possible by suturing should, consequently, be done in completing the operation. Provision for drainage should be made where much oozing is occurring, and temporary drainage is probably better in all cases.

Kangaroo-tendon and floss-silk are the best materials for ligatures. Artificial illumination is desirable in the deeper planes of the operation. The line of the artery runs, approximately, from the center of the manubrium to the center of the right sternoclavicular joint.

The chief causes of death after operation are: secondary hemorrhage, cellulitis, pneumonia, and pericarditis.

Ligation of the Innominate Artery by an Angular Incision (Mott's Operation).—The patient lies supine, with chest raised, head

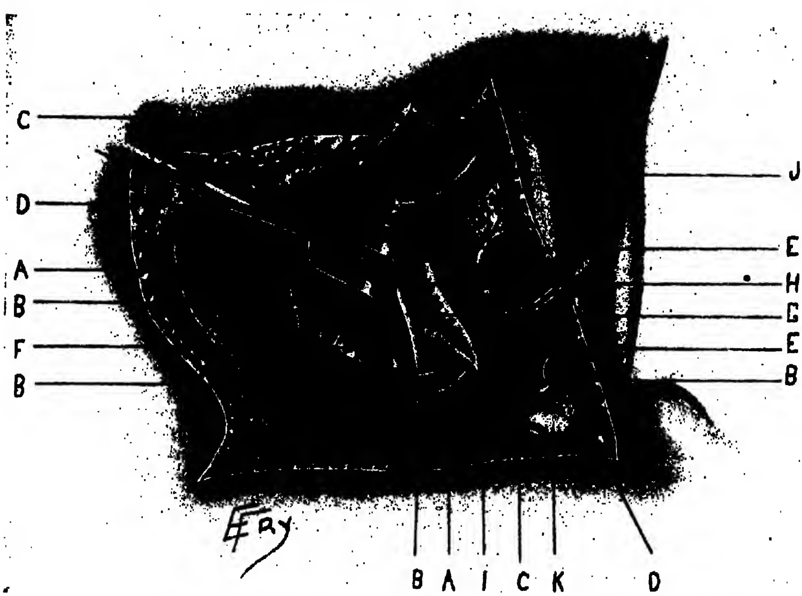

FIG. 238.—LIGATION OF THE INNOMINATE ARTERY BY AN ANGULAR INCISION; ALSO OF THE RIGHT COMMON CAROTID BELOW THE OMOHYOID, AND OF THE VERTEBRAL NEAR ITS ORIGIN.

A, A, Platysma; B, B, B, B, sternomastoid; C, C, sternohyoid; D, sternothyroid; E, innominate artery bifurcating into subclavian and common carotid; F, internal jugular vein; G, pneumogastric nerve; H, vertebral artery; I, trachea; J, thyroid gland; K, right sternoclavicular articulation.

backward, and to opposite side. The surgeon is to the outer side of the shoulder. His assistant stands opposite.

The landmarks are the clavicle, sternomastoid muscle, and sternoclavicular joint.

The incision is >-shaped. The horizontal portion of the incision is made along the upper margin of the inner third of the clavicle for a distance of about 7.5 cm. (3 in.). The oblique portion (meeting the horizontal at an acute angle) is made along the anterior margin of the sternomastoid, for about 7.5 cm. (3 in.) (Fig. 237, A).

Having incised the skin and superficial fascia, the triangular flap thus outlined is dissected upward (Fig. 238). Cut the sternal and

clavicular attachments of the sternomastoid as far as exposed. The sternohyoid and sternothyroid muscles are also cut or are nicked and drawn well inward. Expose and double ligate the anterior jugular vein and divide it between its two ligatures as it lies between the sternomastoid; and also the right inferior thyroid vein. Divide the deep cervical fascia along the original lines of the incision, thus exposing the common carotid. Open its sheath and follow it to its origin, avoiding the recurrent laryngeal nerve. Thus guided to the innominate, clear its trunk—with especial care on the outer side of the pneumo-

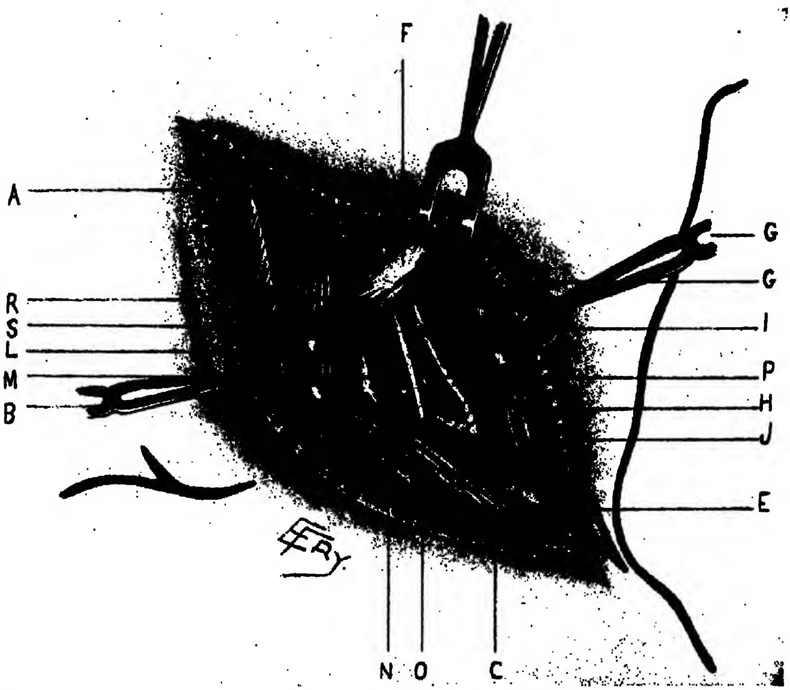

FIG. 239.—LIGATION OF INNOMINATE BY OBLIQUE INCISION; ALSO OF RIGHT COMMON CAROTID BELOW OMOHYOID; VERTEBRAL NEAR ORIGIN; AND INFERIOR THYROID NEAR ORIGIN.

A, Platysma; B, sternomastoid retracted outward and downward; C, right sternoclavicular rticulation; E, manubrium sterni; F, omohyoid; G, sternohyoid; H, sternothyroid; I, thyroid land; J, innominate artery dividing into common carotid and subclavian; L, inferior thyroid; M, ertebral; N, right innominate vein, with subclavian and internal jugular; O, pneumogastric; P, recurrent laryngeal; R, nerves from loop between communicans and descendens hypoglossi; S, superficial cervical nerves.

gastric nerve, right innominate vein, and pleura—and pass the needle from these structures.

Ligation of the Innominate by an Oblique Incision.—The position of the patient and operators, as well as the landmarks of the operation, are the same as for Mott's exposure just given.

The incision begins at the junction of the middle and lower thirds of the anterior border of the right sternomastoid muscle, passes down along the lower third of its anterior margin, and thence sweeps over the upper edge of the episternal notch onto the manubrium sterni (Fig. 237, B, B).

Incise the skin, superficial fascia, platysma, and deep fascia (Fig. 239). Tie the anterior jugular vein between two ligatures; also ligate the transverse branch between the two anterior jugulars if in the way. Draw the sternomastoid outward, and, if necessary, its inner, sternal portion may be divided. Draw inward the sternohyoid and sternothyroid muscles, dividing, if need be, the sternal attachments in whole or in part. Incise the deep cervical fascia over the carotid sheath. Open the sheath and follow the common carotid behind the sternoclavicular articulation to the subclavian and to the innominate, guarding the recurrent laryngeal nerve behind the common carotid sheath. Ligate the right inferior thyroid vein. Clear the innominate artery, avoiding the left innominate vein in front, the right pleura behind, and the right pneumogastric nerve, right innominate vein, and right pleura to the right. By the separation and retraction of the muscles here described less damage is done to the parts and less of a cavity is left than after the operation by angular incision.

Ligation of the Innominate by Partial Bony Resection through Transverse and Vertical Incisions (Bardenheuer's Operation).— The following parts are excised through a combined transverse and vertical incision: the right and left sternoclavicular articulations, the sternal ends of right and left first ribs, the sternal end of the right second rib, and the upper 2.5 cm. (1 in.) of the manubrium, thus exposing the innominate.

The position of the principals in the operation are as in Mott's operation, given above.

The landmarks are the suprasternal notch and manubrium, the sternal ends of the clavicles, and the inferior margin of the thyroid cartilage.

The parts are approached through a double incision. The transverse incision passes along the upper border of the sternum and over the surface of the inner thirds of both clavicles. The vertical incision extends from the lower border of the larynx down the median line, and well on to the manubrium sterni (Fig. 237, D, D).

Carry both incisions through the skin and superficial and deep fascia. In the transverse incision divide the sternomastoid, sternohyoids, and sternothyroids. Subperiosteally resect (with Gigli saw, rongeur, bone-cutting forceps, or chisel) the inner extremities of the left clavicle and the left first rib for about 1.3 cm. (½ in.) of their extent. Having made this exposure of the upper and outer portion of the manubrium upon its left aspect, free, through this approach, the posterior surface of the manubrium subperiosteally. The manubrium is then cut transversely through at a level about 2.5 cm. (1 in.) below its upper border, the division being accomplished, preferably, by a Gigli saw conducted beneath the bone, between it and the periosteum. The sternal ends of the right clavicle and the right first and second ribs, after having been well cleared, are divided close to the outer margin of the sternum, in the same manner as the manubrium was divided. The mass of bone detached by the above cuts is now removed. The

periosteum is then incised in the median line, the inferior thyroid veins ligated, the left innominate vein depressed, the right innominate vein retracted, the right pneumogastric nerve and pleura guarded on the outer side and behind, the innominate artery cleared, and the ligature passed from the pleura and the pneumogastric.

Ligation of the Innominate by Splitting the Manubrium Sterni.—The manubrium is exposed by a transverse incision, divided transversely at its junction with the gladiolus, then split vertically at its center, followed by the separation of the two halves of the manubrium and the exposure of the innominate. Upon completing the operation the bony parts are returned to their normal positions, with or without suturing of the edges of the vertically divided manubrium into apposition.

The patient is supine, with shoulders raised and neck prominent. The surgeon is upon the right side, the assistant opposite.

The landmarks are: the sternoclavicular articulations; lower border of manubrium (marked by the line extending transversely across between the articulations of the second ribs).

The site is reached through a curved transverse incision, passing from the inner third of the anterior surface of one clavicle to the inner third of the anterior surface of the opposite clavicle, and passing down over the manubrium to the junction of its upper and middle thirds (Fig. 237, E).

Having incised the skin, fascia, and anterior borders of the platysma down to the bone, clamp and tie all bleeding vessels. Free the manubrium subperiosteally over its anterior surface downward to the junction of the manubrium and gladiolus, and upward to its superior border. Follow the superior border backward and downward along its posterior aspect, also freeing the surface subperiosteally as far as the junction of the manubrium and gladiolus. Retract the overlying soft parts on the anterior aspect of the manubrium and divide the sternum along the manubriogladiolar junction, accomplishing the division with a Gigli saw, if one can be conducted across beneath the bone, or by bone-cutting forceps. Through the opening thus made by the transverse division carry a Gigli saw from the center of the lower border of the divided manubrium to the center of the suprasternal notch, and divide the manubrium vertically in its center, cutting from the manubriogladiolar junction upward toward the free superior border, the Gigli saw traveling between the posterior surface of the manubrium in front and its periosteum posteriorly. After the completion of the vertical section retract the two halves of the manubrium laterally, incise the posterior periosteum, ligate the inferior thyroid veins, depress the left innominate vein, retract the right innominate vein, guard the right pneumogastric and pleura externally and posteriorly, clear the innominate, and pass the ligature from the pleura and pneumogastric. Where it is wished to suture together the vertical borders of the split manubrium, at the end of the operation, two or three holes should be drilled on each side as soon as the manubrium has been exposed anteriorly

and posteriorly and before its division, the soft parts below being protected by some thin, flat metallic instrument during the drilling.

Ligation of the Common Carotid.—The indications for ligation of the common carotids are wounds of the vessels themselves and of the branches of the external and internal carotids; distal and proximal aneurisms; distal angeiomata; as a temporary ligature; to limit the growth of inoperable tumors; to control hemorrhage from areas supplied by distal branches.

The line of the artery (with the head turned moderately to the opposite side and upward) extends from the sternoclavicular articulation to a point midway between the angle of the jaw and the tip of the

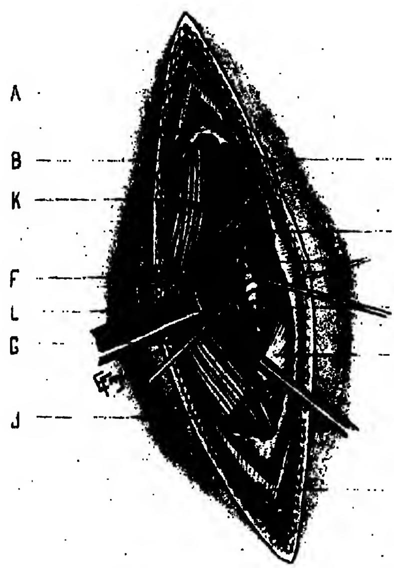

FIG. 240.—LIGATION OF RIGHT COMMON CAROTID ABOVE OMOHYOID.

A, A, Platysma; B, sternomastoid (retracted outward); C, omohyoid (retracted downward); D, sternothyroid; E, common carotid (its sheath incised above omohyoid); F, sternomastoid artery; G, internal jugular vein; H, superior thyroid vein; I, inferior thyroid vein; J, communicating vein between anterior and external jugular; K, one of transversalis colli nerves; L, nerves from loop between descendens and communicans hypoglossi.

mastoid process, that portion of this line between the sternoclavicular articulation and the level of the upper border of the thryoid cartilage representing the common carotid. The course of the artery would be more accurately represented by a line from the clavicle a little external to the sternoclavicular articulation. The anterior margin of the sternomastoid muscle overlaps the carotid throughout. The omohyoid muscle crosses the carotid opposite and directly over Chassaignac's "carotid tubercle" (the costal process of the sixth cervical vertebra), which is about 6.3 cm. (2½ in.) above the clavicle.

The common carotid may be ligated above the omohyoid, which constitutes the place of election, or below the omohyoid, where the

depth of the artery and the nature of the relations makes the operation more difficult and more fatal (Fig. 237. F and G).

Ligation of the Common Carotid Above the Omohyoid Muscle.— The patinet is supine, with shoulders elevated, neck prominent, and chin upward and to opposite side. The surgeon stands on the side of the operation or on the right for both sides.

The landmarks for the vessel are the anterior border of the sterno-mastoid and the cricoid cartilage.

The incision is about 7.5 cm. (3 in.) in length, with its center at the level of the cricoid cartilage, and lying in the line of the artery.

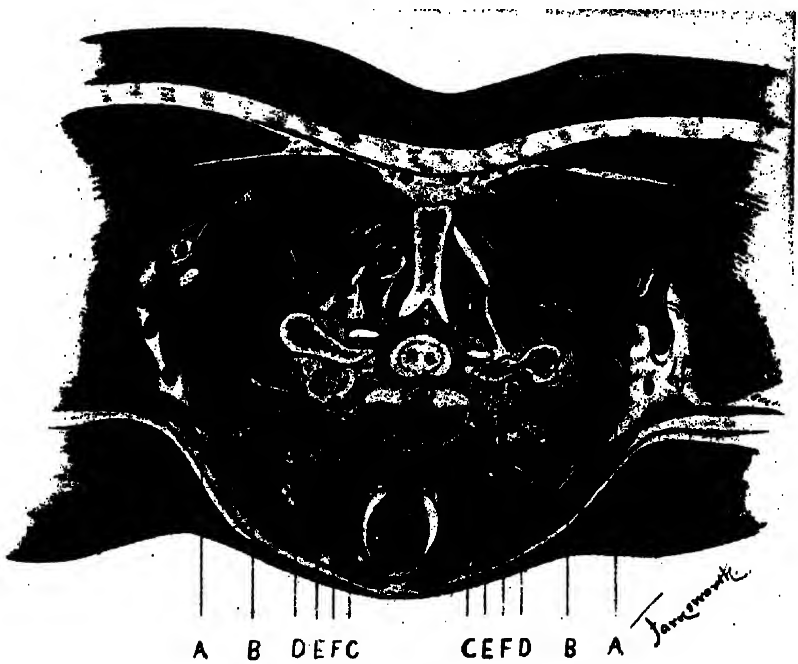

FIG. 241.—CROSS-SECTION OF THE NECK AT THE LEVEL OF THE SEVENTH CERVICAL VERTEBRA. (Modified from Braune.)

A, A, Scaleni muscles; B, B, sternocleidomastoid muscles; C, C, sternohyoid and sternothyroid muscles; D, D, common carotid arteries and internal jugular veins; E, E, vertebral arteries and veins; F, F, inferior thyroid arteries and veins.

Incise the skin, superficial fascia, and platysma. The superficial veins connecting the anterior and external jugulars, and sometimes intercommunicating veins between the fascial and anterior jugular, as well as cutaneous nerves, are encountered (Fig. 240). Divide the deep fascia along the anterior border of the sternomastoid and open up the cellular tissue. The upper border of the omohyoid is here exposed, either by direct incision or by following up the anterior border of the sternomastoid.

Having identified the intersection of the sternomastoid and omohyoid, the omohyoid is retracted downward (or may be divided if in

the way), and the sternomastoid outward. Flexing the chin aids during these manipulations by relaxing the parts. The common carotid is now located as it crosses the carotid tubercle (v. s.) Clear the sheath of the artery, avoiding or tying the sternomastoid artery and the superior and middle thyroid veins. Carefully incise the sheath, approaching from the inner side to avoid the descendens hypoglossi nerve (which is generally upon the antero-external aspect of the sheath) and the internal jugular vein, and see that the artery is freed from its sheath in its entire circumference (Fig. 241). Pass the needle from the internal jugular and pneumogastric nerve.

Ligation of the Common Carotid Below the Omohyoid Muscle.—The position and landmarks are the same as in the above operation.

An incision, about 7.5 cm. (3 in.) in length, is made in the line of the artery, from just below the cricoid cartilage to just above the sternoclavicular articulation (Fig. 237, G).

Incise the skin, superficial fascia, and platysma. Here are encountered the superficial veins between the facial and anterior and external jugular veins and the cutaneous cervical nerves. Divide the deep fascia along the anterior border of the sternomastoid. Expose the inner border of this muscle, flexing the head to relax the parts. The sternohyoid is then exposed and sometimes the underlying sternothyroid. The omohyoid is, ordinarily, not brought into the field of operation. These muscles, if encountered, are retracted in their respective directions, or may be divided as far as necessary. Tie the inferior thyroid veins. The sheath of the vessel is to be exposed as, and with the precautions, mentioned in the above operation. The recurrent laryngeal nerve and the inferior thyroid artery are to be especially guarded in operating at this site.

The ligation of the common carotid is more difficult on the left side, owing to the nearness of the internal jugular vein.

The common carotid may be temporarily ligated, where it is necessary to control bleeding in the field supplied by the vessel or its branches. This is best accomplished by passing a ligature-loop of floss silk beneath the artery, by means of which the vessel is gently lifted forward when it is desired to stop the flow, the ligature being withdrawn at the end of the operation.

Ligation of the External Carotid Artery.—The indications for ligation are: wounds and aneurism of the main trunk and branches, hemorrhage from the areas supplied by the branches, as a palliative in malignant growths, as a preliminary to operations in the general area of supply, and aneurism by anastomosis in the region of the trunks.

The line of the external carotid is the same as the line given for the upper part of the common carotid (p. 672).

The external carotid may be ligated in two sites: below the digastric (between the superior thyroid and lingual branches), the place of election, where the operation is easier and more branches are thus controlled; above the digastric, where the operation is more difficult and more apt

to involve branches of the facial nerve. The digastric muscle crosses the artery about 3.2 cm. (1¼ in.) above its origin, opposite the upper border of the thyroid cartilage. The lingual artery arises opposite the great cornu of the hyoid bone. (Fig. 237, H and I.)

The external carotid may be distinguished from the internal carotid by the presence of its branches and by being to the inner side of the external carotid. The ligation of the external carotid is now generally done where formerly the common carotid was ligated for conditions of the former vessel and its branches—the practicability and desirability of the operation having been demonstrated by the work of Wyeth.

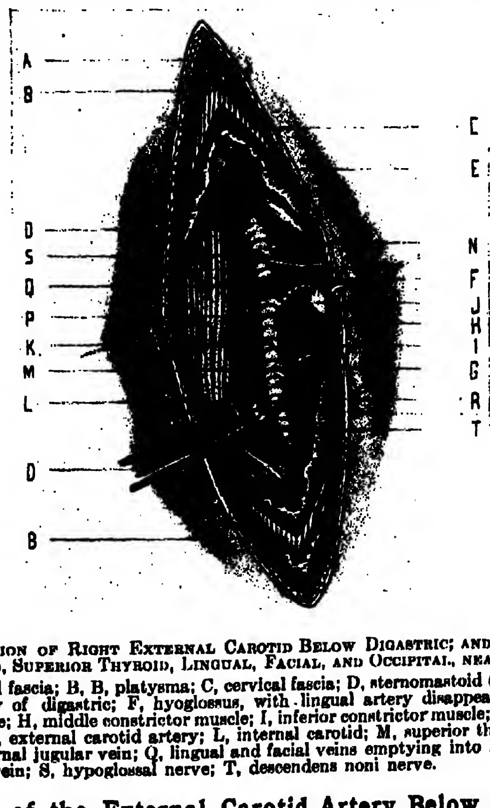

Fig. 242.—Ligation of Right External Carotid Below Digastric; and also of Internal Carotid, Superior Thyroid, Lingual, Facial, and Occipital, near Origin.

A, Superficial fascia; B, B, platysma; C, cervical fascia; D, sternomastoid (retracted outward); E, posterior belly of digastric; F, hyoglossus, with lingual artery disappearing beneath it; G, thyrohyoid muscle; H, middle constrictor muscle; I, inferior constrictor muscle; J, tip of great cornu of hyoid bone; K, external carotid artery; L, internal carotid; M, superior thyroid; N, facial; O, occipital; P, internal jugular vein; Q, lingual and facial veins emptying into internal jugular; R, superior thyroid vein; S, hypoglossal nerve; T, descendens noni nerve.

Ligation of the External Carotid Artery Below the Digastric Muscle.—The position of the principals in the operation is as for the ligation of the common carotid (p. 673).

The landmarks are the sternomastoid muscle, thyroid cartilage, and angle of the jaw.

The incision is about 7.5 cm. (3 in.), extending along the anterior border of the sternomastoid or slightly in front of the border, from the level of the middle of the thyroid cartilage to near the angle of the jaw (Fig. 237, H).

Incise the skin, superficial fascia, and platysma (Fig. 242). Tie any veins which may lie in the line of the incision. Divide the deep

fascia and expose the anterior border of the sternomastoid and draw it outward. Find the posterior belly of the digastric at the upper angle of the wound. Next, locate the hypoglossal nerve, crossing the external carotid below the origin of the occipital artery. Locate the tip of the great cornu of the hyoid bone, opposite which the lingual artery arises. Having fixed the location of these three structures, and avoiding the superior thyroid, facial, and lingual veins, expose the artery opposite the tip of the great cornu of the hyoid. Clear the sheath and pass the ligature between the superior thyroid and lingual branches, guarding the descendens hypoglossi nerve in front and the superior laryngeal nerve passing behind the artery, directing the needle from the internal carotid. The operation is not an easy one and it is often difficult to recognize the branches. Jacobson advises the simultaneous ligation of the superior thyroid, the lingual, and, if possible, the ascending pharyngeal branches, on account of secondary hemorrhage.

Ligation of the External Carotid Above the Digastric Muscle.—The position of the patient and operator is as for the ligation of the common carotid (p. 673).

The landmarks are the line of the artery (page 672) and the ramus of the inferior maxilla.

The incision extends from the tragus of the ear to below the angle of the inferior maxilla, placed just behind the ramus of the jaw, in the line of the artery (Fig. 237, I).

Incise the skin and superficial fascia. Avoid or doubly ligate and incise the tributaries of the external jugular and facial veins. Divide the deep fascia. Expose the anterior border of the sternomastoid and retract outward. Expose the posterior belly of the digastric and stylohyoid and draw downward, partially or entirely dividing them, if necessary. Avoid the branches of the facial nerve. Expose the parotid gland and draw upward and forward, thus exposing the vessel. Clear the artery and open its sheath, and pass the ligature around the artery prior to its entrance into the substance of the parotid gland. Repair by suturing whatever may have been incised.

Ligation of the Lingual Branch of the External Carotid.—The lingual is usually ligated in connection with operations upon the tongue.

The first portion of the lingual lies between the external carotid and the hyoglossus muscle, the second portion lies under the hyoglossus, and the third portion extends beyond the hyoglossus. The artery is generally ligated in its first or second parts; of these, the second part is preferable.

Ligation of the Second Part of the Lingual Beneath the Hyoglossus.—The patient is supine, with shoulders raised, neck prominent, head to opposite side, and chin upward. The surgeon is on the side of the operation, cutting from before backward on the right, and vice versâ.

The landmarks are the lower border of the inferior maxilla, the facial artery crossing the inferior maxilla, and the hyoid bone.

The incision is curved, beginning just below and external to the symphysis menti, and ending just below and internal to the crossing of the facial artery over the inferior maxilla, its center being just above the greater cornu of the hyoid bone (Fig. 237, L).

Incise the skin, superficial fascia, platysma, and deep fascia. Avoid or ligate the tributaries of the facial, anterior jugular, or temporomaxillary veins. Incise the transverse cervical fascia over the submaxillary gland, exposing the gland and retracting it upward, out of its bed, over the margin of the lower jaw (Fig. 243). Incise transversely

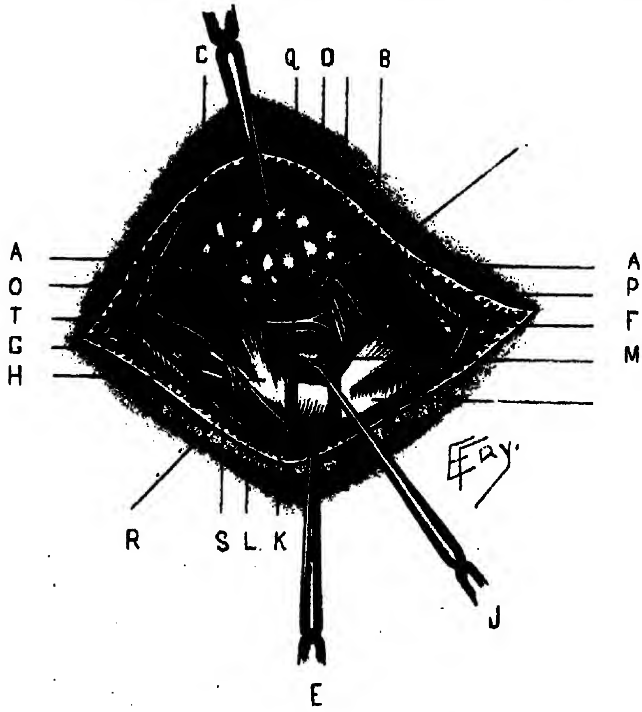

FIG. 243.—LIGATION OF RIGHT LINGUAL ARTERY BENEATH HYOGLOSSUS.

A, A, Platysma; B, transverse cervical fascia over submaxillary gland; C, deep transverse cervical fascia under submaxillary gland; D, submaxillary gland; E, hyoid bone; F, anterior belly of digastric; G, posterior belly of digastric; H, stylohyoid; I, mylohyoid; J, hyoglossus; K, omohyoid; L, thyrohyoid; M, lingual artery seen through incision in hyoglossus; N, submental artery; O, tributary of temporomaxillary vein; P, tributary of anterior jugular vein; Q, ranine vein; R, transverse cervical nerve; S, superior laryngeal nerve and vessels; T, hypoglossus nerve.

the deep cervical fascia, exposing the submaxillary gland by lifting it out of its bed, and identify the mylohyoid muscle in the anterior aspect of the wound. Expose the two bellies of the digastric, and firmly retract them downward at their point of attachment to the hyoid bone, which steadies the parts and renders the hyoglossus more prominent. Clear the surface of the hyoglossus and identify the hypoglossal nerve crossing its anterior aspect. The ranine vein crosses the same surface just below and parallel with the nerve and at about the same level as the artery lies on the opposite side of the muscle. Retract both

the hypoglossal nerve and the ranine vein upward. Divide the hyoglossus transversely for about 1.3 cm. (½ in.) just above and parallel with the hyoid bone. This incision falls just over the artery, which generally bulges into the opening as soon as it is made, or through which it is easily reached. Having isolated the artery, trace it backward until the dorsalis linguæ branch is reached, so that the ligature may be placed upon its proximal side. Having passed the ligature, replace the submaxillary gland and close the wound. Before completing the operation the fascia of the submaxillary gland may be sutured over it, and the incision in the hyoglossus may be repaired by suturing, if either be considered indicated.

Ligation of the Facial Branch of the External Carotid.—The indications for ligation of the facial are wounds and aneurism.

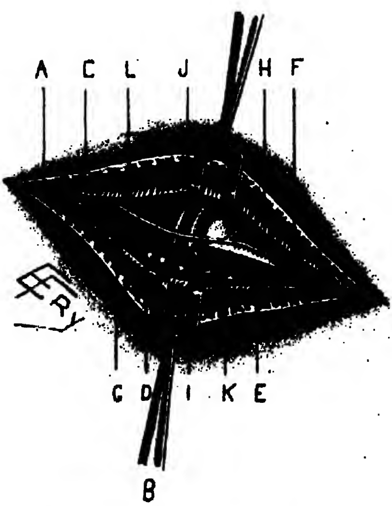

FIG. 244.—LIGATION OF RIGHT FACIAL OVER BORDER OF INFERIOR MAXILLA.

A, Cervical fascia; B, platysma; C, deep cervical fascia; D, submaxillary gland; E, mylohyoid muscle; F, inferior maxilla; G, masseter muscle; H, depressor anguli oris; I, facial artery; J, facial vein; K, submental artery; L, supramaxillary nerve.

The usual site for ligation is along the line where the vessel crosses the inferior maxilla. It may also be ligated near its origin.

Ligation of the Facial Artery Over the Inferior Maxillary.—The patient is supine, with shoulders raised and the head thrown backward to the opposite side. The surgeon stands upon the side of the operation or on the right for both operations.

The landmarks are the anterior margin of the masseter muscle and the horizontal portion of the inferior maxilla.

The incision, about 2.5 cm. (1 in.) in length, is placed along and under cover of the lower border of the lower jaw, with its center over the course of the artery (at the anterior margin of the masseter muscle) (Fig. 237, M).

Incise the skin, superficial fascia, platysma, and deep fascia, when

the artery should come into view, with the facial vein just posterior to it. Avoid branches of the facial nerve (Fig. 244). Pass the ligature from the vein.

Ligation of the Occipital Branch of the External Carotid.—The indications for ligation are wounds, aneurism of the scalp, and hemorrhage from abscess.

The artery may be ligated behind the mastoid process (the more usual position) or near its origin, according to the site of lesion requiring ligature.

Ligation of the Occipital Branch of the External Carotid Behind the Mastoid Process.—The patient is supine, with shoulders and head elevated, and head turned well to the opposite side (or the

FIG. 245.—LIGATION OF LEFT OCCIPITAL ARTERY BEHIND MASTOID PROCESS.
A, Posterior cervical fascia; B, trapezius muscle; C, sternomastoid; D, splenius capitis; E, trachelomastoid; F, occipital artery and venæ comites, lying upon complexus muscle; G, great occipital nerve; H, lesser occipital nerve; I, posterior external jugular vein.

patient rests slightly to one side). The surgeon stands behind the head on the side of the operation.

The landmarks are the mastoid process and the external occipital protuberance.

The incision is about 5 cm. (2 in.) in length, beginning from the tip of the mastoid process and extending toward the external occipital protuberance (Fig. 237, N).

Having incised the skin and fascia, divide the posterior half of the sternomastoid and its strong aponeurosis, then the splenius capitis, next, as many fibers of the trachelomastoid as are in the way (Fig. 245). Relax and retract the muscles by turning the head to the side of the operation. Expose the artery deep down between the mastoid process of the temporal and the transverse process of the atlas, resting upon the superior oblique and complexus muscles. Having separated from it the accompanying veins, and having guarded the vein from the mastoid

foramen, the ligature is passed. The lesser occipital nerve runs on the posterior surface of the sternomastoid, near its posterior border, and the great occipital nerve pierces the trapezius muscle near its outer border.

Ligation of the Temporal Branch of the External Carotid Artery.—The indications for ligation are wounds and aneurism.

The main trunk may be ligated just above the root of the zygoma. The anterior and posterior branches may be ligated about 3.8 to 5 cm. (1½–2 in.) above the zygoma.

Ligation of the Temporal Artery Just Above the Zygoma.—The patient lies supine, with shoulders raised and head to the opposite side. The surgeon stands on the side of the operation, cutting from above downward on the right, and vice versâ, or stands on the right side for both operations, cutting from above downward.

FIG. 246.—LIGATION OF RIGHT TEMPORAL JUST ABOVE ZYGOMA.

A, Temporal artery, with its anterior and posterior bifurcations, and its transverse facial, middle temporal, and anterior auricular branches; B, temporal vein, with branches corresponding to those of artery; C, temporal branches of auriculotemporal nerve; D, branch of temporofacial division of facial nerve; E, temporal fascia.

The landmarks are the tragus of the ear, the condyle of the jaw, and the zygoma.

The incision is vertical, about 2.5 to 3.8 cm. (1–1½ in.) in length, over the line of the artery, with its center over the zygoma and extending downward in the interval between the tragus of the ear and the condyle of the lower jaw (Fig. 237, O).

Incise the skin and dense subcutaneous tissue and parotid fascia, when the artery will be exposed lying quite superficial, as it crosses the zygoma. Avoid the accompanying vein posteriorly, also avoid the branches of the temporofacial division of the facial nerve and the auriculotemporal nerve (Fig. 246). The needle is passed without difficulty, as the vessel is quite superficial.

Ligation of the Middle Meningeal Artery in the Cranium.—The indication for the ligation of this vessel is intracranial hemorrhage.

The common trunk may be tied or the anterior or posterior branches, as indicated (Fig. 237, P, Q, R). The point of bifurcation is generally given by anatomists as corresponding, on the exterior of the skull, with a point 3.8 cm. (1½ in.) behind the external angular process of the frontal bone, and 3.8 to 4.5 cm. (1½–1¾ in.) above the zygoma. The anterior branch runs in a groove on the great ala of the sphenoid and the anterior inferior angle of the parietal. The posterior branch crosses the squamous portion of the temporal and then enters the groove on the posterior inferior angle of the parietal bone. In the young these measurements are less.

The following practical anatomic points may be summarized: That no parts of the middle meningeal artery or its anterior or posterior branches have fixed relations, except the main trunk at its exit from the foramen spinosum and the anterior branch where it crosses the sphenoparietal suture to reach the antero-inferior angle of the parietal. That the common trunk is generally present. That the anterior branch may be given off from the orbital branch of the lacrymal branch of the ophthalmic. That a tendency to symmetry exists upon the two sides of the skull, but is not constant. That the anterior branch runs through a bony canal in the anterior inferior angle of the parietal bone in the majority of cases.

Ligation of the Main Trunk of the Middle Meningeal Artery in the Cranium through a Trephine Opening Exposed by a Curved Oblique Incision.—The patient is supine, with the head supported, shaved, and turned to the opposite side. The surgeon stands on the side of the operation.

The landmarks are the following: a point is selected as the center of the trephine opening which will fall over the trunk of the artery proximal to its bifurcation, and which is taken to be about 3.8 cm. (1½ in.) behind the external angular process of the frontal bone and 2.5 cm. (1 in.) above the zygoma.

The incision begins at the external angular process of the frontal bone, passes obliquely downward and backward to the posterior end of the zygoma, and from this point upward and backward above the auricle (Fig. 237, P).

Having incised the skin and temporal fascia, ligate the superficial temporal artery and vein, guarding the auriculotemporal nerve and branches of the facial (Fig. 247). Then carry the incision along the posterior border of the temporal muscle through the periosteum to the bone. Detach the temporal muscle forward subperiosteally, baring parts of the squamous, parietal, and sphenoid bones, guarding the deep temporal arteries. Firmly retract the soft parts thus freed upward and forward. Using a trephine of a diameter of about 3.8 cm. (1½ in.), place its center over a point about 3.8 cm. (1½ in.) behind the external angular process and 2.5 cm. (1 in.) above the zygoma. Having removed the disk of bone (which is here thin) expose the the artery, and pass the needle carefully to avoid wounding the brain. In completing the operation the disk of bone may be replaced or not, according to the individual ideas of the surgeon. Allow the periosteum and soft parts to reoccupy their normal positions. Suture the margins of the severed periosteum with buried catgut. Repair, by gut suturing, any muscle tissue which may have been cut, and close the skin incision.

The following comments may be made: This incision of Kocher, together with the subsequent retraction of the soft parts, involves less injury to the parts than the turning downward or upward of a semilunar or horseshoe flap, which is the method of approach most frequently adopted. According to the researches of Plummer, the osteoplastic flap operation of Hartley-Krause furnishes the best method

of exposing the main trunk of the middle meningeal artery and its branches. If the above trephine opening expose the artery inconveniently near the circumference, the opening may be enlarged in the direction of the artery with rongeur forceps.

The **anterior branch of the middle meningeal artery** may be exposed by selecting a point for the center of the trephine opening which will fall over the anterior branch just beyond the bifurcation of the main trunk, which is taken to be about 3.8 cm. ($1\frac{1}{2}$ in.) behind the external angular process of the frontal bone, and from 3.8 cm. to 4.5 cm. ($1\frac{1}{2}$–$1\frac{3}{4}$ in.) above the zygoma.

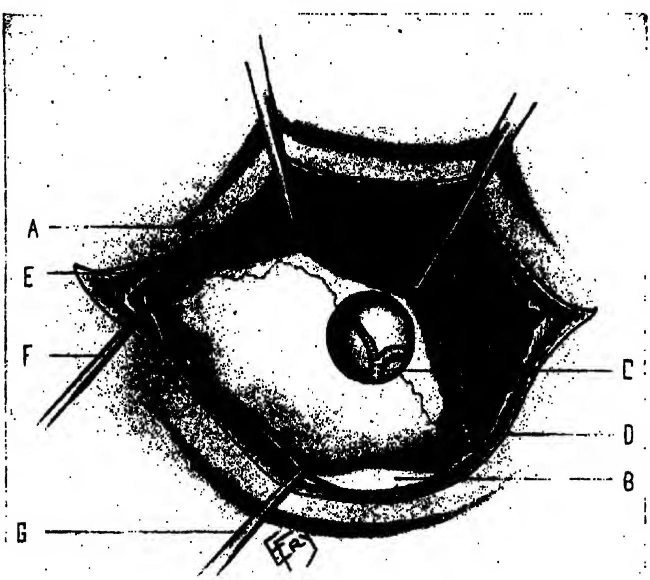

FIG. 247.—LIGATION OF TRUNK OF RIGHT MENINGEAL THROUGH TREPHINE OPENING IN TEMPORAL FOSSA BY CURVED OBLIQUE INCISION.

A, Temporal muscle (its posterior border retracted upward and forward); B, zygomatic arch, and temporal fossa just above; C, main trunk and anterior and posterior branches of middle meningeal, exposed through trephine opening (which is here shown somewhat too high); D, deep temporal artery; E, superficial temporal artery and vein; F, auriculotemporal nerve (retracted backward); G, branches of facial nerve (retracted downward and backward).

The **posterior branch of the middle meningeal artery** may be exposed through a trephine opening, the center of which will fall over the posterior branch in the groove of the parietal bone, and is taken to be at the intersection of a line drawn horizontally backward on a level with the roof of the orbit, and one drawn vertically upward from directly behind the mastoid process, which point of intersection lies just below the parietal eminence (Jacobson).

Either branch may also be exposed through an osteoplastic flap method.

Ligation of the Internal Carotid Artery.—The indications for ligation of the internal carotid are wounds and aneurisms, and when ligated the vessel is exposed near its origin. The line of the

artery is practically the same as that of the external carotid, or possibly a little to the outer side of that line at its lower part.

The incision lies slightly posterior to the incision for the external carotid artery, that is, along the anterior border of the sternomastoid, instead of just in front of it, with the center of the incision about 1.3 cm. (½ in.) above the upper border of the thyroid cartilage (Fig. 237, S).

The steps of the operation are at first the same as those for exposing the external carotid below the digastric. The artery (external carotid) is first sought (all the structures mentioned in that operation, page 675, being encountered) and traced to its bifurcation, and thus the internal carotid is exposed, the external carotid being drawn inward and the digastric upward. In opening the sheath special care must be taken to guard the internal jugular vein, pneumogastric nerve, cervical sympathetic, and ascending pharyngeal artery, the needle being passed from the vagus and internal jugular vein (Fig. 242, L).

Ligation of the Subclavian Artery.—The chief indications for ligation of this artery are wounds, aneurisms, and as a preliminary step for the control of hemorrhage in extensive operations about the shoulder and upper extremity.

But few successful cases of ligation of the first portion of the right subclavian are recorded, and fewer of the left, the ligation being particularly hazardous, especially upon the latter side. Nor is ligation of the second portion to be recommended, owing to the depth and relations of the artery. The third portion is the part of the artery usually selected for ligature (Fig. 237, T). Ligation of the first portion of the subclavian differs slightly upon the two sides, owing to the anatomic relations.

The course of the artery is represented by a curve, with convexity upward, at the base of the posterior triangle of the neck, beginning at the sternoclavicular articulation and ending at the center of the inferior border of the clavicle, its midpoint being about 1.3 (½ in.) above the superior border of the clavicle.

Ligation of the First Portion of the Right Subclavian by an Angular Incision.—The position of the principals, the landmarks, and the incision are the same as for the ligation of the innominate by an angular incision.

Having incised the skin and superficial fascia, this triangular flap is dissected, as in ligation of the innominate. The anterior jugular vein is doubly ligated and divided, and the external jugular similarly treated, if in the way. Divide the deep fascia and expose and sever the sternal and clavicular heads of the sternomastoid. Divide the sternohyoid and sternothyroid either in whole or in part. Expose the common carotid, carefully retracting the internal jugular vein and pneumogastric nerve outward and displacing or doubly ligating any overlying veins. Identify the subclavian vein by following down the common carotid on its postero-external aspect to the bifurcation. Clear the subclavian artery, carefully guarding the recurrent laryngeal and phrenic nerves and vertebral artery. Displace the pleura down-

ward and outward with the tip of the finger, and pass the needle from below (from the pleura). The vertebral should also be secured at the same time and through the same incision, to accomplish which the internal jugular and pneumogastric nerve are now retracted inward and the vertebral exposed by a few strokes of the knife as it lies between the longus colli and scalenus, guarding the phrenic and recurrent laryngeal nerves and the inferior thyroid artery. When required by the circumstances, the right sternoclavicular articulation may be excised, as in the operation of the ligation of the innominate by partial bony resection.

Ligation of the First Portion of the Left Subclavian by an Angular Incision.—The steps of the operation are similar to those for the ligation of the first portion of the right subclavian, up to the exposure of the common carotid and internal jugular. Here the common carotid and pneumogastric are retracted inward, the internal jugular is drawn outward and downward, and, with it, the left innominate vein. At this stage the head is bent forward to relax the parts. Special care is here given to identifying the thoracic duct before proceeding, the duct arching from the seventh cervical vertebra forward and downward over the subclavian artery in front of the scalenus anticus, and emptying into the left subclavian vein at the junction with it of the left internal jugular, being imbedded in the loose areolar tissue of the part, making it often difficult to find and sometimes dividing into several branches. Having safeguarded the important neighboring structures, follow down the common carotid with the finger until the subclavian is identified, on a plane posterior and external to that of the former vessel. The artery is then to be freed, carefully guarding the pleura, the sheath is opened, and the needle passed from the pleura. If more room be required than given by the above incision, or if it be required to ligate the vessel nearer the arch, an excision of the sternoclavicular articulation can be made.

Ligation of the Third Portion of the Subclavian.—The patient is supine, with shoulders raised, head thrown back and to opposite side, and the operated shoulder depressed by the arm drawn downward and placed under the back (to open out the posterior cervical triangle). The surgeon stands in front of the shoulder.

The landmarks are the posterior border of the sternomastoid (which corresponds with the outer border of the scalenus anticus), the anterior border of the trapezius, and the middle of the clavicle.

After having drawn the skin of the posterior cervical triangle down over the clavicle with the left hand, an incision about 7.5 cm. (3 in.) is made transversely over the clavicle down to the bone, from the posterior border of the sternomastoid to the anterior border of the trapezius, and with its center about 2.5 cm. (1 in.) internal to the center of the superior border of the clavicle (Fig. 237, T).

This incision will divide the skin, fascia, plastysma, some supraclavicular nerves, and may be a connecting vein between the cephalic and internal jugular, but will avoid the external jugular, which passes

through the deep fascia above the clavicle. The incision will lie about 2.5 cm. (½ in.) above the clavicle when the tension upon the skin is relaxed (Fig. 248). The margins of the sternomastoid and trapezius will be exposed and, if more room be needed, may be divided along the clavicle as far as necessary. The deep cervical fascia is next incised, the external jugular vein being carefully exposed and retracted, or divided between double ligatures. Tributary veins of the external jugular are to be similarly treated, especially the transversalis colli and suprascapular. Generally the transversalis colli artery lies transversely above the incision, and the suprascapular transversely below it, under the clavicle and out of the way, but one or both may present

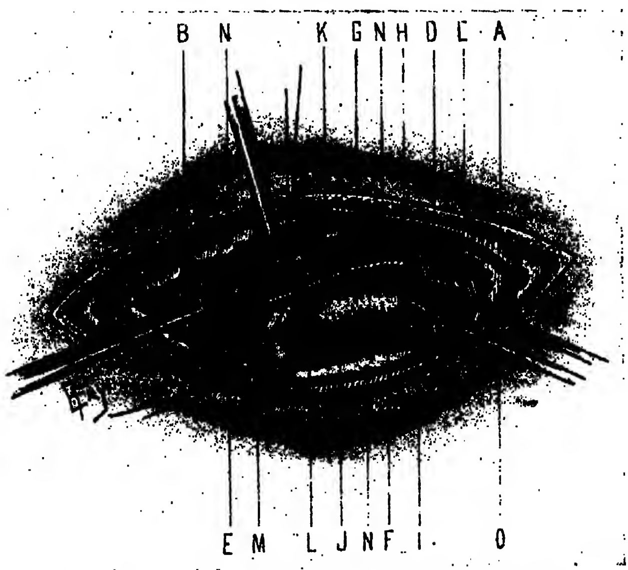

FIG. 248.—LIGATION OF THIRD PART OF RIGHT SUBCLAVIAN.

A, Platysma; B, trapezius; C, sternomastoid (posterior border incised); D, scalenus anticus; E, posterior belly of omohyoid (retracted upward); F, clavicle; G, third part of subclavian; H, transversalis colli artery; I, suprascapular artery; J, subclavian vein; K, upper end of external jugular vein (divided and retracted), with transversalis colli vein and communicating branch to anterior jugular; L, lower end of external jugular (divided and retracted), with suprascapular branch; M, brachial plexus; N, N, N, supraclavicular nerves; O, deep cervical fascia.

in the field, and are to be carefully preserved for collateral circulation. Retract the posterior belly of the omohyoid upward if in the way. Identify the outer margin of the scalenus just under the outer margin of the sternomastoid as a guide to the artery, and follow its outer border downward until the finger reaches the tubercle on the upper border of the first rib, which lies between the subclavian vein in front and the subclavian artery behind, when the artery will be recognized and may be traced upward. Expose the lowest cord of the brachial plexus for the purpose of henceforth avoiding it (as it has been mistaken and ligated for the artery). The subclavian vein will lie anteriorly and inferiorly to the artery. Open the sheath, clear the artery, and pass

the needle from the brachial plexus, guarding the subclavian vein and the pleura.

Ligation of the Vertebral Artery.—The artery is ligated for wounds, traumatic aneurisms, and in connection with the ligation of the innominate artery (in order to prevent secondary hemorrhage).

The most usual site of ligation is in the first or cervical portion, being but rarely tied in the third or occipital portion.

The patient is supine, with shoulders raised, neck prominent, and head to opposite side. The surgeon stands to the right in operating upon either vertebral.

The landmark of the operation is the anterior border of the sternomastoid.

The incision is about 7.5 cm. (3 in.) in length, extending along the anterior border of the sternomastoid, ending below at the clavicle (as for the ligation of the common carotid below the omohyoid).

Divide the skin, superficial fascia, and anterior portion of the platysma, when branches of the superficial cervical nerve, and communicating veins between the anterior and external jugular veins, are encountered, and are to be treated as indicated. Incise the deep cervical fascia, exposing the anterior border of the sternomastoid, which is to be drawn outward; and the omohyoid, which is to be retracted downward and inward; and also the sternohyoid, which is drawn inward. Having freed the attachment of the inner aspect of the common sheath, the carotid, internal jugular, and pneumogastric are drawn outward from over the vertebral artery. The prevertebral fascia is then incised vertically between the carotid tubercle (transverse process of the sixth cervical vertebra) and the arch of the inferior thyroid artery (where it turns inward to the posterior surface of the thyroid gland), where the vertebral artery will be found ascending, partly covered by the longus colli, to the foramen in the transverse process of the sixth cervical vertebra, having the anterior scalenus muscle and phrenic nerve to its outer side and the longus colli muscle and recurrent laryngeal nerve to its inner side, and the inferior thyroid artery and vein and the vertebral vein lying over it. All these structures, therefore, are to be displaced in the most convenient directions, as the finger seeks the vertebral artery in the above triangular space. The pleura lies below and internally. The thoracic duct, on the left, crosses the artery from within outward. The artery is to be exposed, and the ligature passed with especial care, in order to avoid, as far as possible, the fibers of the sympathetic, some of which are apt to be included in the ligature (Fig. 238, H).

The vertebral may also be ligated by an incision made along the posterior border of the sternomastoid, followed by the inward retraction of that muscle (with or without a partial division of its clavicular attachment), but is a less simple operation than the above technic. The artery may also be ligated in the suboccipital triangle.

Ligation of the Internal Mammary Branch of the Subclavian Artery.—This vessel is but rarely ligated, except for wounds, when

it is usually ligated at the site of injury. If the artery has retracted out of reach, it is ligated in the interspace above or below.

The artery is most readily reached in the first, second, or third interspace, especially in the second.

Ligation of the Internal Mammary in the Second Intercostal Interspace.—The patient is supine, with the chest supported from behind (to increase the width of the intercostal spaces).

The landmarks are the outer border of the sternum, the lower border of the second, and the upper border of the third costal cartilages.

The incision is transverse in direction and about 6.3 cm. (2½ in.) in length, beginning over the center of the sternum and passing outward

FIG. 249.—LIGATION OF RIGHT INTERNAL MAMMARY IN SECOND INTERCOSTAL SPACE.

A, Pectoralis major; B, external intercostal muscle, continued to sternum by anterior intercostal membrane; C, internal intercostal muscle; D, margin of sternum; E, endothoracic fascia; F, pleura; G, internal mammary artery and venæ comites.

over the center of the interspace between the second and third costal cartilages (Fig. 237, V).

Divide the skin, fascia, pectoralis major, anterior intercostal membrane (running downward and inward), internal intercostal muscle (running downward and outward), and the endothoracic fascia, when the artery will be found lying upon the pleura, with the venæ comites to either side. Separate the artery, and pass the needle with especial care to avoid the pleura (Fig. 249).

Ligation of the Axillary Artery.—The chief indications for ligation are wounds, aneurisms, and for hemorrhage in inoperable axillary growths.

The artery is ligated in its third part by preference, and in its first part if the third part be not available. Ligation of the third part of

the subclavian is usually considered preferable to that of the first portion of the axillary (Figs. 250, C, and 237, W).

The line of the vessel is represented, when the arm is at a right angle to the trunk and the hand supine, by a line extending from the middle of the clavicle to the junction of the anterior and middle thirds of the outer axillary wall, between the anterior and posterior folds of the axilla. It is to be remembered that when the arm is at a right angle with the body the axillary vein is drawn across the first part of the artery.

Ligation of the First Part of the Axillary Artery by a Curved Transverse Incision Below the Clavicle.—The patient lies upon the back, at the edge of the table, with the upper thorax raised and the

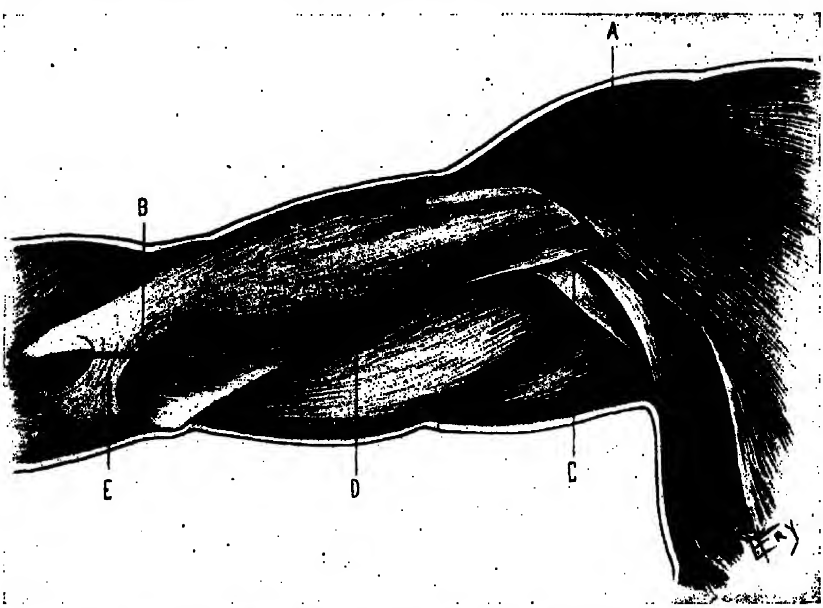

FIG. 250.—INCISIONS FOR LIGATING RIGHT AXILLARY AND BRACHIAL ARTERIES.
A, Junction of anterior and middle thirds of outer axillary wall; B, center of bend of elbow; C, ligation of third part of axillary; D, of brachial in middle of arm; E, of brachial at bend of elbow.

shoulder backward. The surgeon stands near the thorax on the left for the operation of the left side, and near the head on the right for the operation of the right side, or between the abducted limb and the body on either side.

The landmarks are the clavicle, the sternoclavicular articulation, and the coracoid process.

A curved incision is made in the infraclavicular fossa, beginning just external to the sternoclavicular joint, dipping at its lowest point about 1.3 cm. (½ in.) below the clavicle, and ending at the coracoid process (Fig. 237, W).

Incise the skin, platysma, supraclavicular nerves, and fascia. Carefully guard the cephalic vein and branches of the acromial thoracic

artery at the outer part of the wound on account of the collateral circulation. Divide the clavicular origin of the pectoralis major throughout the wound. Clear the areolar tissue beneath the pectoralis major. Expose the upper border of the pectoralis minor and draw it downward. Divide obliquely downward and outward, near the coracoid process, the costocoracöid membrane, through which pass the cephalic

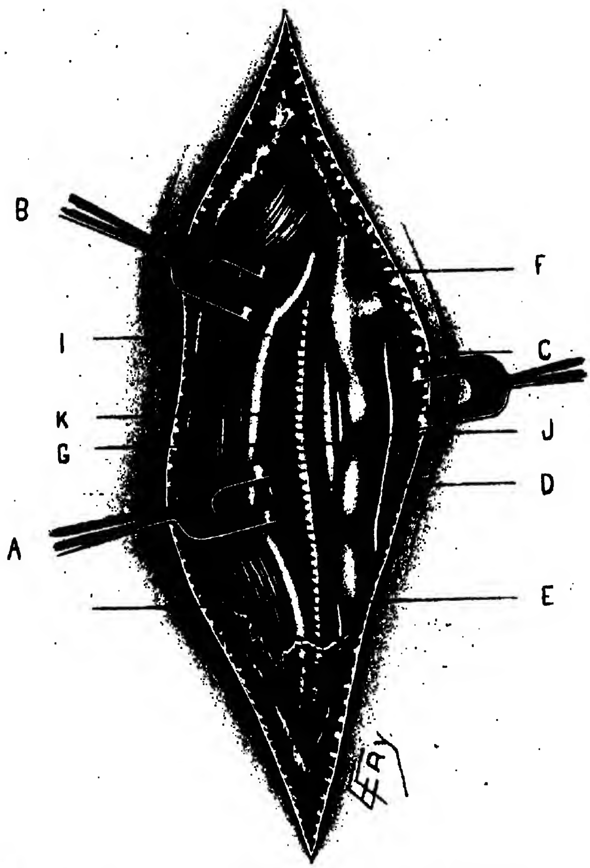

FIG. 251.—LIGATION OF THIRD PART OF RIGHT AXILLARY.

A, Coracobrachialis (retracted outward); B, pectoralis major; C, teres major; D, triceps; E, axillary artery; F, basilic vein, becoming axillary vein after receiving two brachial venæ comites; G, right brachial vena comes; I, median nerve; J, internal cutaneous nerve; K, K, ulnar nerve.

vein, branches of the acromiothoracic artery, and the anterior thoracic nerves, and displace it upward and outward. The cephalic vein, indicating the position of the axillary vein, is generally closely adherent to the costocoracoid membrane. Expose the sheath and clear the artery, which lies between the axillary vein on the inner side and the brachial plexus on the outer, aided in the exposure by bringing the arm nearer the body, when the axillary vein will be carried from over the artery

to its inner side. The ligature is placed above the acromiothoracic branch. The incised pectoralis major muscle is closed by gut-suturing. This is the easiest and most frequent ligation of the first portion in the rare cases in which a ligation at this site is done. The first part may also be exposed by an oblique incision in the groove between the pectoralis major and the deltoid.

Ligation of the Third Portion of the Axillary Artery.—The patient is supine at the edge of the table, with shoulders raised and arm at a right angle with the body and slightly rotated outward. The

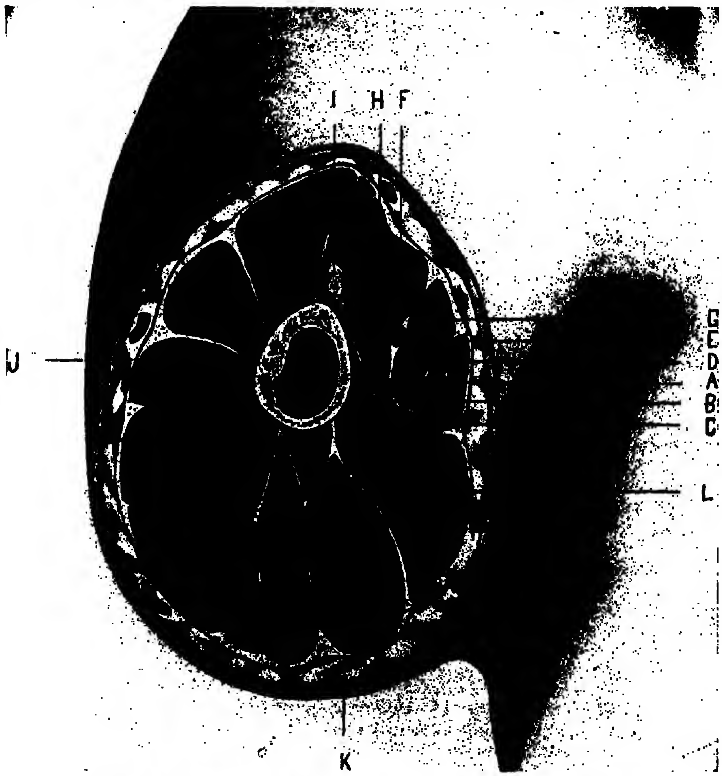

FIG. 252.—CROSS-SECTION OF RIGHT ARM AT THE AXILLARY LEVEL.
A, Axillary artery and vein; B, ulnar nerve; C, musculospiral nerve; D, median nerve; E, internal cutaneous nerve; F, musculocutaneous nerve; G, coracobrachialis muscle; H, biceps; I, pectoralis major muscle and biceps tendon; J, deltoid; K, triceps; L, latissimus dorsi. (Modified from Esmarch.)

surgeon stands between the arm and the chest on either side. The axilla is shaved.

The landmarks are the junction of the anterior and middle thirds of the external axillary wall and the coracobrachialis.

An incision is made about 7.5 cm. (3 in.) in length, beginning at the middle of the outlet of the axilla, at the junction of the anterior and middle thirds of its outer wall, and passing downward along the inner border of the coracobrachialis (Fig. 250, C).

Having incised the integument and fascia, expose the inner border

of the coracobrachialis (Fig. 251). Draw this muscle and musculocutaneous nerve outward. The median nerve is exposed and also drawn outward. The internal cutaneous and ulnar nerves are drawn inward. Venæ comites are generally present at the lower part of the axilla, and sometimes the basilic vein, which have to be guarded. Again, the axillary vein alone may be present to the inner side of the artery (Fig. 252). Pass the needle from the vein, ligating the artery as far from a large branch as possible.

Ligation of the Brachial Artery.—The indications for ligation are wounds and traumatic aneurisms.

The sites of ligation are the middle of the arm (preferably) and at the bend of the elbow.

The line of the artery (with the arm extended and abducted and hand supine) from the junction of the anterior and middle thirds of the outer wall of the axilla to the center of the bend of the elbow (Fig. 250, A and B).

Ligation of the Brachial Artery in the Middle of the Arm.—The limb is extended and abducted with the hand supine. The surgeon stands to the outer side of the limb, cutting from above downward on the right, and from below upward on the left.

The landmarks are the inner border of the coracobrachialis and the biceps and the line of the artery.

The incision is from 5 to 7.5 cm. (2 to 3 in.) in length, extending along the inner border of the biceps in the line of the artery, opposite the middle of the arm (Fig. 250, D).

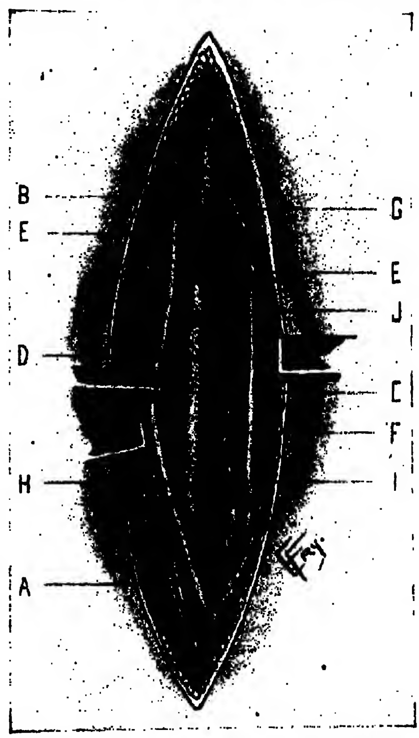

FIG. 253.—LIGATION OF RIGHT BRACHIAL AT MIDDLE OF ARM.

A, Biceps; B, coracobrachialis (retracted outward); C, triceps; D, brachial artery and branches; E, brachial venæ comites and communicating branches; F, basilic vein; G, branch from basilic to cephalic vein; H, median nerve; I, ulnar nerve; J, internal cutaneous nerve.

The skin and the fascia having been divided, the inner border of the biceps must be clearly recognized and retracted outward, when the artery will generally be found under its inner margin, the median nerve usually crossing the front of the artery at its middle, the internal cutaneous nerve lying to the inner side (Fig. 253). The venæ comites and basilic vein are to be separated from the artery. The needle is passed from the nerve. The artery is not as easily found in this situation as its superficial position would suggest (Fig. 254). Its exposure

is made easier by an assistant holding the limb by the wrist, so that it cannot rest on the table, where the triceps is apt to be pushed upward and may protrude the inferior profunda artery and the ulnar nerve instead of the brachial artery and median nerve (Heath). In ligating higher than the middle third the artery lies to the inner side of the coracobrachialis, the median nerve to the outer side, and the ulnar nerve to the inner.

Ligation of the Brachial Artery at the Bend of the Elbow.—The limb is extended (not overextended) and abducted. The surgeon

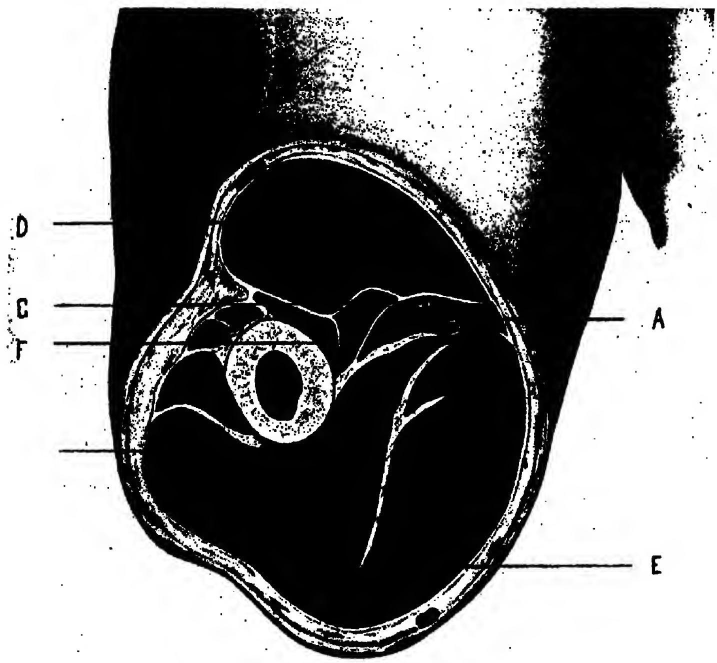

FIG. 254.—CROSS-SECTION OF THE MIDDLE OF THE RIGHT ARM.
A, Brachial artery and veins and inferior profunda artery and median and ulnar nerves; B, musculospiral nerve and superior profunda artery; C, nutrient vessels; D, biceps muscle; E, triceps; F, brachialis anticus muscle. (Cross-section modified from Braune.)

stands to the outer side of the limb, cutting from above on the right and from below on the left.

The landmark of the operation is the inner border of the biceps tendon.

An incision about 5 cm. (2 in.) in length is made in the internal bicipital fossa, along the inner border of the biceps tendon, its center corresponding to the "fold of the elbow." This incision will be oblique, and its upper end will commence opposite the tip of the internal condyle of the humerus. It is well to compress the veins above, to get an idea of their position at the elbow, and thus avoid them if possible. Ordinarily the incision will lie above and to the outer side of the median basilic (Fig. 250, E).

Having incised the skin and superficial fascia, isolate the median basilic vein and the accompanying internal cutaneous nerve and retract them inward (Fig. 255). Incise in the direction of the original wound the deep fascia and bicipital fascia; the latter (passing inward and downward) is to be incised to as limited an extent as possible. Beneath the bicipital fascia lies the artery with its venæ comites, the median nerve generally lying out of the way and to the inner side, nearer the upper than the lower part of the wound (Fig. 256). Pass the needle from the side of the ulnar nerve. Resuture the bicipital fascia with catgut.

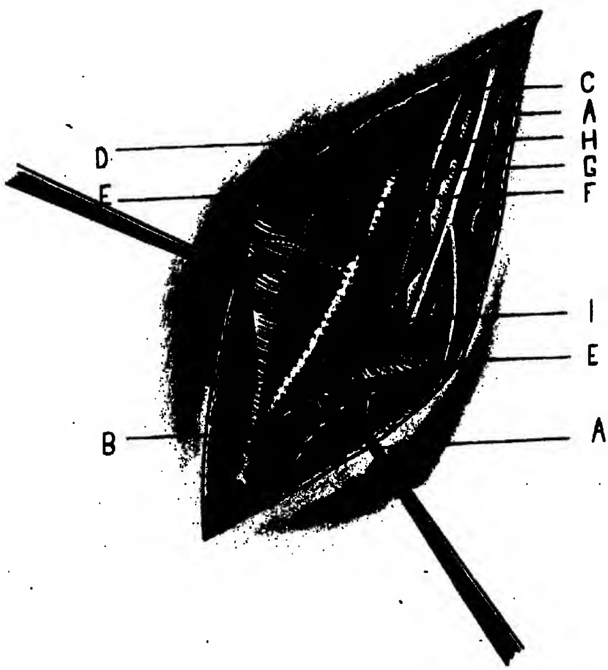

FIG. 255.—LIGATION OF THE RIGHT BRACHIAL AT THE BEND OF THE ELBOW. A, A, Median basilic vein; B, median cephalic vein; C, internal cutaneous nerve and branches; D, biceps; E, E, bicipital fascia; F, brachial artery; G, brachial venæ comites and communicating branch; H, median nerve; I, brachialis anticus muscle.

Ligation of the Radial Artery.—The ligation of this vessel is usually resorted to for the control of hemorrhage due to a wound in some part of its course.

The sites for ligation are the upper forearm (rarely), the middle forearm, the lower forearm (preferably), and on the back of the hand, in the "tabatière" (rarely). In the palm the arch may be tied in case of wounds, under which circumstances it is ligated at any site (Fig. 257, A, B, C, D).

The line of the artery: In the forearm (with hand supine—from the center of the bend of the elbow to the inner side of the forepart of

the styloid process of the radius (Fig. 257, H and I). At the wrist—from the inner side of the forepart of the styloid process to the base of the first interosseous space. In the palm—the artery runs about 2 cm. (¾ in.) nearer the wrist than does the superficial palmar arch (which corresponds with a line continued across the palm on a level with the lower border of the outstretched thumb).

Ligation of the Radial in the Upper Third of the Forearm.—The hand is supine, with wrist extended. The surgeon stands outside of the limb, cutting downward on the right and upward on the left. The assistant holds the fingers with one hand and grasps the forearm with the other.

FIG. 256.—CROSS-SECTION OF RIGHT ARM JUST BELOW THE ELBOW-JOINT.

A, Brachial artery dividing into radial and ulnar, with venæ comites; B, median basilic vein; C, radial recurrent artery and radial and interosseous nerves; D, ulnar nerve and posterior ulnar recurrent artery; E, median nerve and anterior ulnar recurrent artery; F, biceps tendon; G, supinator longus muscle; H, extensor carpi radialis longior; I, extensor carpi radialis brevior; J, extensor carpi ulnaris; K, anconeus; L, pronator radii teres; M, flexor sublimis digitorum; N, flexor carpi ulnaris (a fascial line is seen between its two parts); the brachialis anticus muscle lies just below the brachial artery. The flexor carpi radialis lies just to the right of the pronator radii teres. (Cross-section modified from Braune.)

The landmarks are the line of the artery and the inner border of the supinator longus.

The incision is from 5 to 7.5 cm. (2 to 3 in.) in the line of the artery, with its center over the center of the upper third of the forearm (Fig. 257, A).

Having incised the skin and superficial fascia the radial or median vein may be met. Divide the deep fascia and open up the space between the supinator longus (its fibers running directly downward) and the pronator radii teres (its fibers running downward and outward

(Fig. 258). The artery lies under the edge of the supinator longus and upon the insertion of the pronator radii teres. The radial nerve

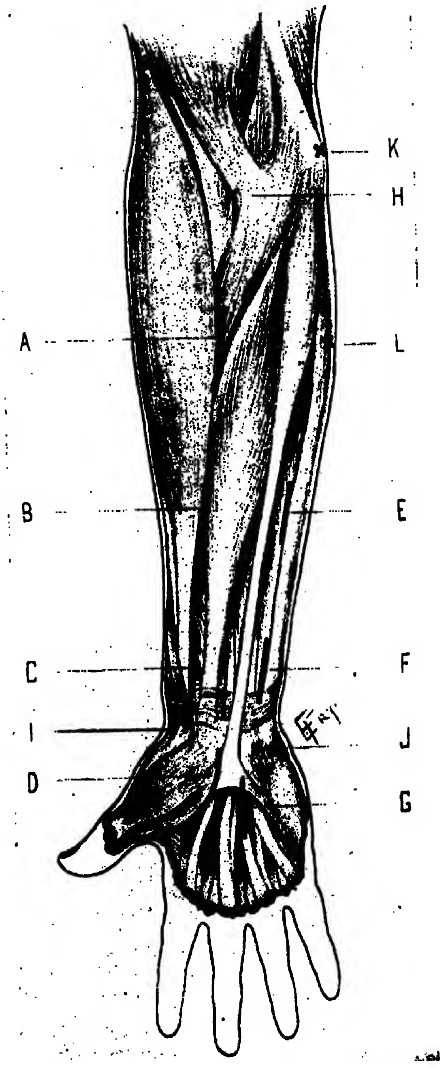

Fig. 257.—Incisions for Ligating Right Radial and Ulnar Arteries, and Superficial and Deep Palmar Arches.

A, Ligation of radial in upper third of forearm; B, of radial in middle third; C, of radial in lower third; D, of deep palmar arch; E, ligation of ulnar in middle third of forearm; F, of ulnar in lower third; G, of superficial palmar arch; H, center of bend of elbow; I, antero-internal aspect of styloid process of radius; J, radial side of pisiform bone; K, anterior aspect of inner condyle of humerus; L, point on inner aspect of forearm at junction of upper and middle thirds.

lies well to the outer side. Unless one recognize the inner margin of the supinator longus, there is the possibility of hitting off the wrong intermuscular septum and getting too near the middle of the forearm

(Fig. 259). The anterior surface of the supinator longus (and not its inner border) appears at first in operating upon the muscular, and this must be well retracted outward.

Ligation of the Radial in the Lower Third of the Forearm.—The landmarks are the tendons of the supinator longus and the flexor carpi radialis.

An incision, from 2.5 to 5 cm. (1 to 2 in.) long, is made vertically in the center of the interval between the tendons of the supinator longus and flexor carpi radialis (Fig. 257, C).

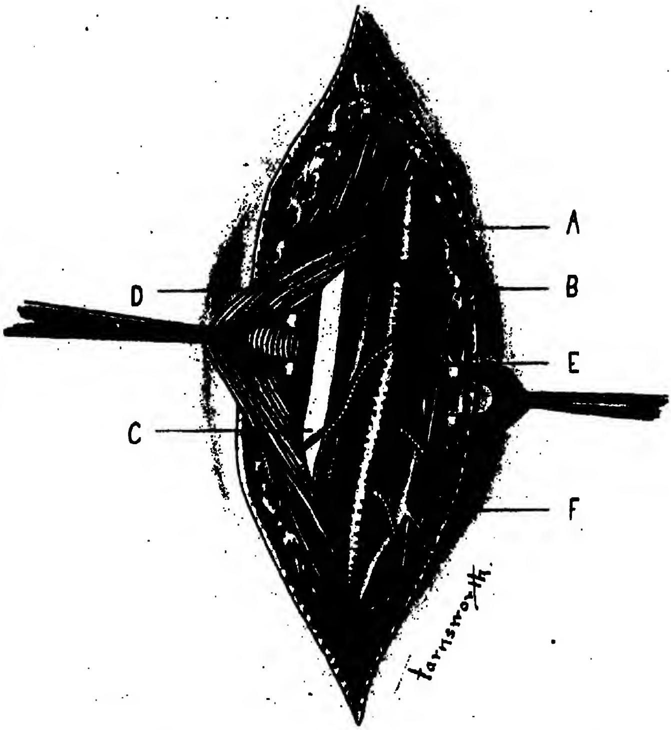

FIG. 258.—LIGATION OF THE RIGHT RADIAL ARTERY IN THE UPPER PART OF THE FOREARM. A, Radial artery; B, radial venæ comites; C, radial nerve; D, supinator longus muscle; E, pronator radii teres muscle; F, flexor carpi radialis muscle. (Modified from Deaver.)

Having incised the skin and superficial fascia, the radial vein, or a large branch, and often the superficialis volæ artery, are met and are displaced to one side (Fig. 260). The deep fascia is divided, and the interval between the tendon of the supinator longus, externally, and the tendon of the flexor carpi radialis, internally, is opened up and the artery and its venæ comites are found between them, accompanied by the anterior branch of the musculocutaneous nerve (Fig. 261).

Ligation of the Deep Palmar Branch of the Radial.—The limb is supine, with hand extended. An assistant steadies the fingers and wrist. The surgeon cuts from above downward on both sides.

The landmark is the oblique crease running downward and outward

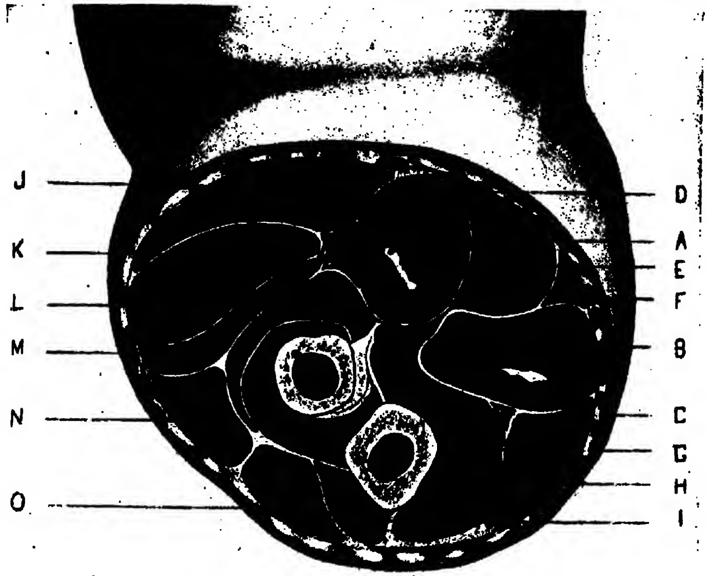

FIG. 259.—CROSS-SECTION OF THE UPPER THIRD OF THE RIGHT FOREARM.

A, Radial artery and branches, veins, and nerve; B, ulnar and interosseous arteries, veins, and median nerve; C, ulnar nerve; D, pronator radii teres muscle; E, flexor carpi radialis; F, subcutaneous vein and nerve; G, flexor profundus digitorum; H, flexor carpi ulnaris; I, anconeus; J, supinator longus; K, extensor carpi radialis longior; L, supinator brevis; M, extensor carpi radialis brevior; N, extensor communis digitorum; O, extensor carpi ulnaris. (Cross-section modified from Braune.)

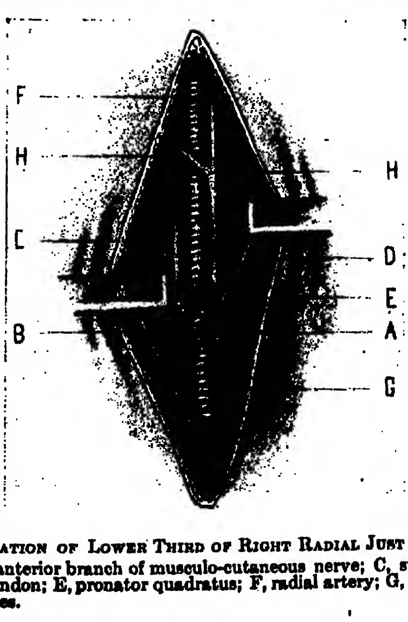

FIG. 260.—LIGATION OF LOWER THIRD OF RIGHT RADIAL JUST ABOVE WRIST.

A, Radial vein; B, anterior branch of musculo-cutaneous nerve; C, supinator longus tendon; D, flexor carpi radialis tendon; E, pronator quadratus; F, radial artery; G, superficialis volæ artery; H, H, radial venæ comites.

from the junction of the thenar and hypothenar eminences and partially circumscribing the thenar eminence.

An incision is made from the junction of the thenar and hypothenar eminences—running along the thenar crease toward the metacarpophalangeal joint of the index-finger, with the center of the incision opposite the center of the ball of the thumb (Fig. 257, D).

Having incised the skin and superficial fascia, expose and ligate the superficial palmar arch (crossing the palm on a level with the lower border of the outstretched thumb) (Fig. 262). The muscles of the thenar eminence are now exposed, and these, with the annular ligament, are incised at the upper part of the wound to as limited an extent as possible (Fig. 262). The interval between the flexor tendons of the index-finger and its accompanying lumbrical muscle, on the one hand, and the muscles of the thumb, on the other, is made out and

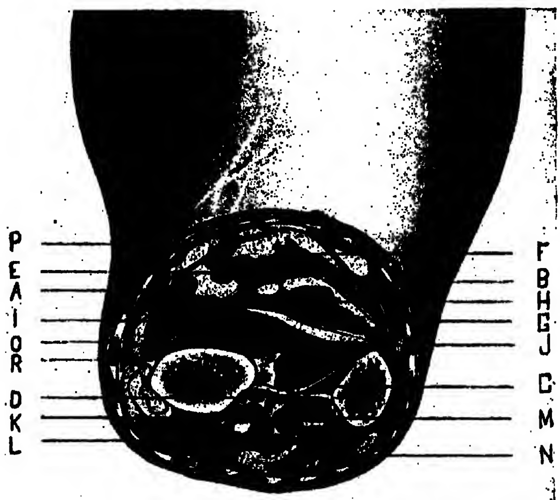

FIG. 261.—CROSS-SECTION OF THE LOWER THIRD OF THE RIGHT FOREARM.

A, Radial artery and veins; B, ulnar artery, veins, and nerve; C, anterior interosseous artery; D, posterior interosseous artery; E, median nerve; F, flexor sublimis digitorum muscle; H, flexor digitorum profundus; I, flexor longus pollicis; J, pronator quadratus; K, extensor indicis pollicis; L, extensor proprius pollicis; M, extensor indicis; N, extensor communis digitorum; O, supinator longus tendon; P, flexor carpi radialis. (Modified from Braune.)

opened up by deep retraction, guarding the branches of the median nerve. In the interval thus exposed by retraction is seen the abductor obliquus pollicis, which is to be divided vertically, when the arch will be found under it, running transversely from between the adductor obliquus pollicis and the adductor transversus pollicis onto the deep fascia covering the interossei, and about 2 cm. ($\frac{4}{5}$ in.) nearer the wrist than does the superficial arch. The needle is to be carefully passed in the deep wound to avoid the nerves and veins.

Ligation of the Ulnar Artery.—The indications for the ligation of this vessel are the same as for the ligation of the radial.

The sites for ligation are the upper third of the forearm (rarely), the middle third, the lower third (commonly), and the superficial palmar arch (for wounds at that site) (Fig. 257, E, F, G).

The line of the upper third of the artery corresponds with the line from a point about 1.3 cm. ($\frac{1}{2}$ in.) below the center of the bend of the elbow, passing to the inner side with a gentle curve (convexity to the ulnar side), to a point at the junction of the upper and middle thirds of the following line. The lower two-thirds corresponds with the

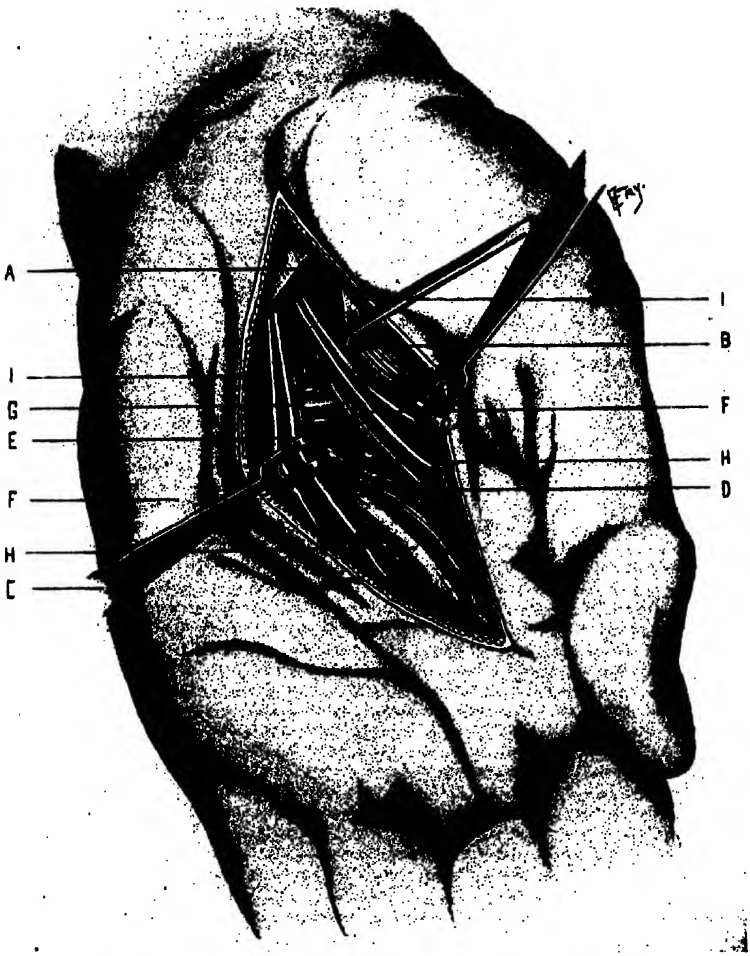

FIG. 262.—LIGATION OF LEFT SUPERFICIAL AND DEEP PALMAR ARCHES.
A, Annular ligament; B, flexor brevis pollicis (part of its origin from annular ligament incised); C, tendons of flexor sublimis digitorum and outer lumbrical (drawn inward); D, adductor obliquus pollicis; E, adductor transversus pollicis; F, F, branches of median nerve; H, H, superficial palmar arch; G, deep palmar arch and its venæ comites; I, I, superficial vein.

line from the anterior surface of the internal condyle of the humerus to the radial side of the pisiform bone (Fig. 257, H, L, and K, J).

Ligation of the Ulnar Artery in the Middle Third of the Forearm.—The position is as for the ligation of the radial artery.

The landmark is the line of the artery as given above, for the

muscular landmarks at the middle of the forearm are difficult to recognize.

The incision is about 7.5 cm. (3 in.), placed in the line of the artery, with its center corresponding with the center of the forearm (Fig. 257, E).

Incise the skin and the superficial fascia. The anterior ulnar vein and the anterior ulnar branch of the internal cutaneous nerve are likely to be encountered (Fig. 263). Divide the deep fascia somewhat to the outer side of the skin incision, as the flexor sublimis digitorum is generally slightly overlapped by the flexor carpi ulnaris. In this

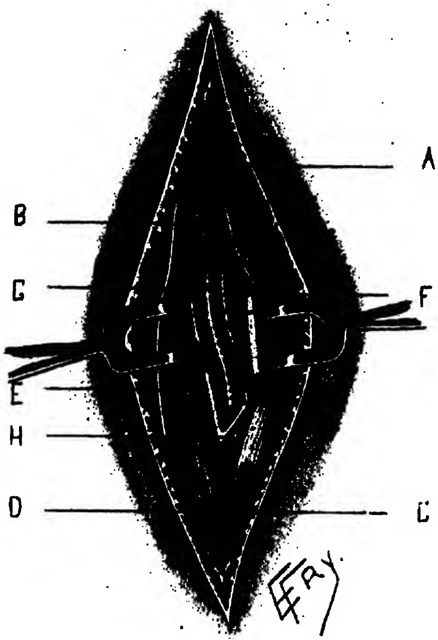

Fig. 263.—Ligation of Right Ulnar in Upper Part of Middle Third.
A, Anterior ulnar vein; B, anterior branch of internal cutaneous nerve; C, flexor carpi ulnaris; D, flexor sublimis digitorum; E, flexor profundus digitorum; F, ulnar nerve; G, ulnar artery; H, venæ comites.

deep fascia the intermuscular plane between the flexor carpi ulnaris and the flexor sublimis digitorum is sought by exposure and by the sense of touch. A muscular branch will often lead to it. These muscles are retracted well apart, when the ulnar nerve is first encountered between them, and, following inward on the same plane, the artery will be found on the flexor profundus surrounded by the venæ comites, and with the ulnar nerve to the ulnar side (Fig. 264). It is sometimes exceedingly difficult to hit off the intermuscular space and to find the artery when once in it. Remember that the even anterior margin of the flexor carpi ulnaris slightly overlaps the flexor sublimis digitorum at this level. Also remember, when once in the intermuscular space,

not to pass below the ulnar nerve, and thus go too deeply on the ulnar side of the forearm, but rather work inward from the level of the nerve.

Ligation of the Ulnar Artery in the Lower Third of the Forearm.—The landmark here is the outer border of the flexor carpi ulnaris.

The incision is about 5 cm. (2 in.) in length, ending about 2.5 cm. (1 in.) above the pisiform bone, and placed between the tendon of the flexor carpi ulnaris and the innermost tendon of the flexor sublimis digitorum. (As the innermost tendon of the flexor sublimis digitorum is not always recognizable, the incision is generally placed to the outer side of the tendon of the flexor carpi ulnaris—Fig. 257, F.)

FIG. 264.—CROSS-SECTION OF THE MIDDLE OF THE RIGHT FOREARM.

A, Flexor carpi radialis; B, median nerve; C, supinator longus; D, radial artery, veins, and nerve; E, flexor longus pollicis; F, extensor carpi radialis; G, extensor ossis metacarpi pollicis; H, flexor sublimis digitorum; I, flexor carpi ulnaris; J, ulnar artery, veins, and nerve; K, flexor profundus digitorum; L, anterior interosseous vessels; M, extensor indicis; N, extensor carpi ulnaris; O, extensor minimi digiti; P, extensor communis digitorum. (Cross-section modified from Braune.)

Having incised the skin and superficial fascia, avoid the anterior ulnar vein or its branches (Fig. 265). Divide the deep fascia. Partly flex the wrist to relax the structures and retract the flexor carpi ulnaris to the ulnar side. The artery will be found upon the flexor profundus digitorum with the venæ comites closely surrounding it and the ulnar nerve lying closely to the ulnar side (Fig. 261).

Ligation of an Intercostal Artery.—The intercostal arteries are sometimes ligated for hemorrhage in their course, or as a preliminary step to an operation upon the thorax.

The landmark to the artery is the lower border of the rib in the groove of which the special artery runs, or the upper border, in case it be the lower branch of the intercostal artery.

The patient lies supine, and is so turned as to render the site of

operation prominent, with the chest supported below, so as to increase the width of the intercostal spaces. The surgeon stands on the side of the operation, the assistant opposite.

Ligation of an Intercostal Artery by an Intercostal Incision.—An incision about 5 cm. (2 in.) is made parallel with and just below the lower border of the indicated rib, or just above the upper border, as the case may be.

Incise the skin and superficial fascia. As to what muscle, and as to what amount of muscle tissue, as well as fascia, will have to be further incised in the line of the original incision before the intercostal muscles are reached, will depend upon the site at which the artery is to be exposed. Having passed through the overlying muscle covering

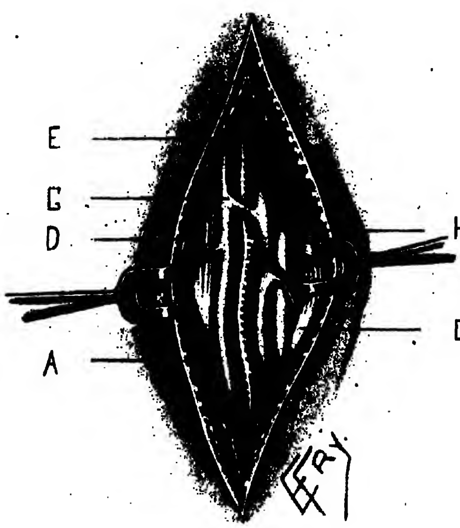

FIG. 265.—LIGATION OF LOWER THIRD OF RIGHT ULNAR JUST ABOVE THE WRIST.
A, Anterior ulnar vein; C, tendon of flexor carpi ulnaris; D, tendon of flexor sublimis digitorum; E, ulnar artery; G, ulnar venæ comites; H, ulnar nerve.

of the thoracic wall, the intercostal fascia is met and incised, then the external intercostal muscle (if operating anywhere between the tubercles of the ribs behind and the costal cartilages in front). The two cut margins of the external intercostals are then drawn upward and downward and the artery sought as it lies partially or entirely concealed in the inferior intercostal groove, with the intercostal nerve below and vein above. The artery may be drawn out of its groove and down into view by the curved tip of the aneurism needle. The vessel should be doubly ligated (its supply coming from both directions). The incised intercostal muscle and fascia may be sutured with gut in closing the wound. If difficulty in exposing the artery be experienced, the rib may be exposed subperiosteally, as in the following operation,

to be described. It is to be remembered, in operating posteriorly to the angle of the rib, that the intercostal artery has not yet reached the inferior groove of the upper rib, but lies between the two ribs and has not divided into its upper and lower branches. If it be desired to ligate the upper and lower branches of the intercostal (anywhere between the angle and costal cartilages), the incision is made midway between the ribs and, after retracting the cut external intercostal muscle, the upper branch is sought in the above manner and the lower branch is found along the upper border of the lower rib. Both are doubly ligated. The upper intercostal artery is often so small as to be difficult or impossible to find.

Ligation of an Intercostal Artery by Partial Subperiosteal Excision of Rib (Hartley's Operation).—An incision about 6 cm. (2½ in.) is made parallel with and directly over the center of the rib.

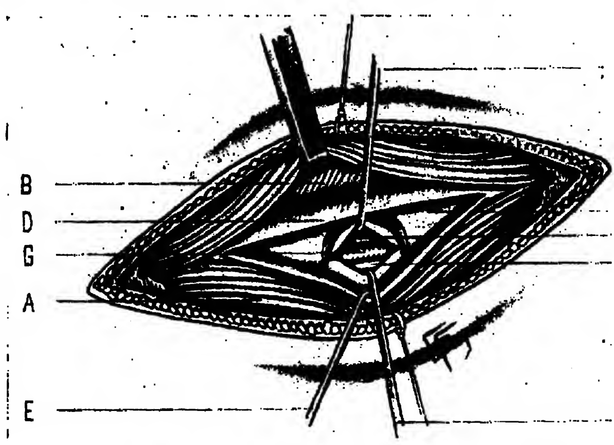

FIG. 266.—LIGATION OF LEFT INTERCOSTAL ARTERY, IN LOWER ANTERIOR THORACIC REGION, BY PARTIAL EXCISION OF A RIB.

A, Thoracic muscles; B, external intercostal muscle; C, rib, with half-button of bone bitten out with rongeur forceps; D, periosteum, incised over center of rib; E, lower half of anterior layer of periosteum retracted downward; F, F, posterior layer of periosteum incised and retracted upward and downward, showing intercostal vessels beneath; G, intercostal artery; H, intercostal vein; I, intercostal nerve. (Hartley's method.)

The above incision passes through the skin, superficial fascia, and overlying thoracic muscles (according to the site of the operation), deep fascia, and periosteum (Fig. 266). With periosteal elevator free the lower half of the anterior surface, the inferior groove, and the lower half of the posterior surface of the rib, all subperiosteally. Then, with rongeur bone-forceps, bite out a "half-button" of bone from the bared lower half of the rib, being careful to insert the lower blade of the rongeur between the detached periosteum and the rib. After the half-button of bone is removed, the position of the artery is plainly evident, and the vessel is exposed by incising through the periosteal membrane directly over it. The artery may also be exposed by the ordinary method of subperiosteal excision of about 4 cm. (1½ in.) of rib throughout its entire thickness.

Ligation of the Abdominal Aorta.—The indications for ligation are iliac and inguinal aneurisms, and primary and secondary hemorrhage, in cases where no other means are possible.

The site for ligation is between the origin of the inferior mesenteric (between 2.5 and 5 cm., or 1 to 2 in., above the bifurcation) and the bifurcation.

The line of the artery extends from a point in the anterior median line, on a level with the lower border of the twelfth dorsal vertebra, to a point a little to the left of the umbilicus, on a level with the highest points of the iliac crests.

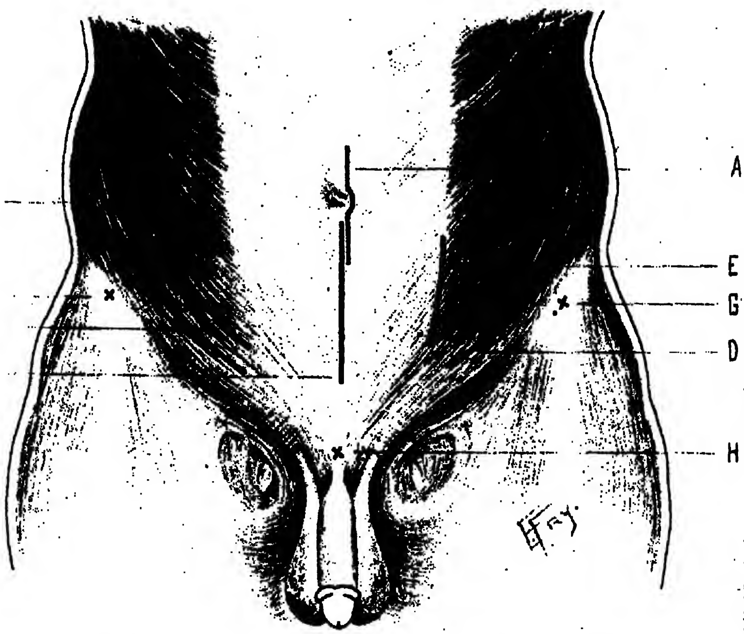

FIG. 267.—INCISIONS FOR LIGATIONS IN THE ABDOMINOPELVIC REGION.

A, Exposure of abdominal aorta by transperitoneal route, through median incision over umbilicus; B, exposure of internal iliac, common iliac, and abdominal aorta by retroperitoneal route through oblique incision parallel with Poupart's ligament; C, exposure of external, internal, and common iliacs by transperitoneal route, through median incision below umbilicus; D, of external and deep epigastric, retroperitoneally, through oblique incision parallel with Poupart's ligament; E, of common, internal, and external iliacs, transperitoneally, through vertical incision in linea semilunaris; F, of external iliac, transperitoneally, through intramuscular incision; G, G, anterior superior iliac spines; H, symphysis pubis.

Ligation of the Abdominal Aorta by the Transperitoneal Method.—The abdomen is opened in the median line and the posterior parietal peritoneum is opened over the artery.

The patient lies in the supine position with the shoulders raised and the knees slightly flexed. The surgeon stands on the right side. The assistant is opposite.

The landmarks are the median, vertical abdominal line, and the transverse line on the level with the highest points of the iliac crest.

The incision is made about 10 cm. (4 in.) in length in the linea

alba, with its center corresponding with the umbilicus, the incision passing slightly to the left of the navel, to avoid the round ligament of the liver and urachus (Fig. 267, A).

The peritoneal cavity having been opened in the usual manner, the small intestines and mesentery are well retracted upward and to the sides. Guided to the artery by its known position and by its pulsation, the peritoneum covering the vessel is carefully divided between the inferior mesentery and its bifurcation into the iliacs. The clearing of the artery should be done with especial care, as inclusion of the sympathetic nerve fibers is otherwise apt to take place, and is supposed to have occurred in one case which quickly ended fatally. A flat ligature should be used (kangaroo tendon, chromicized gut, and silk, flat and round, have been used). The needle should be of special shape, and should be passed in the direction away from the inferior vena cava. The above technic constitutes the most desirable form of operation, though one of the most successful cases, as to length of life, was through a posterior retroperitoneal exposure.

Ligation of the Abdominal Aorta Through a Retroperitoneal Approach.—The artery is here approached from the anterolateral abdominal region, the peritoneum being pushed back from the iliac vessels until the aorta is reached and exposed. The operation is practically similar to that for the exposure and ligation of the common iliac extraperitoneally, the site being reached by an extension of those steps (Fig. 267, B, except on left side, and Fig. 268). The patient is placed so as to be tilted toward the left right side, the surgeon standing behind the patient, upon the side of the operation (the left). An extension of the incision employed for the common iliac is carried further upward to give the necessary room; and, if still required, additional room may be gotten by a second incision running parallel with the ribs, at a right angle to the main incision. The incision is made upon the left side, its general direction being from just within the anterior superior iliac spine toward the tip of the tenth rib, and the aorta is reached by following up the common iliac in the peeling back of the peritoneum from the iliac fascia. The separation of the parts and exposure of the common iliac are, otherwise, the same as for the ligation of that vessel. The vessel is thus less satisfactorily exposed than by the intra-abdominal operation, and there is greater difficulty in avoiding the sympathetic nerve-cords that surround the vessel. The ligature is placed upon the same site as in the intra-abdominal operation, and the inferior vena cava is guarded in passing the needle.

Ligation of the Common Iliac Arteries.—The indications for ligation are aneurisms, wounds, the arrest of hemorrhage from distal parts, and preparatorily to other operations.

The vessel is ligated in as nearly the middle of its course as possible.

The line of the artery is indicated in the following manner: draw a line transversely across the abdomen, on a level with the highest points of the iliac crests, which will cross the abdominal aorta at its bifurcation, draw a second line transversely across the abdomen on a

level with the anterior superior iliac spines, which will cross the common iliacs at their bifurcation; draw a third line from a point on the first line about 1.3 cm. (½ in.) to the left of its center (which is the linea alba), to a point midway between the anterior superior iliac spine and the symphysis pubis. That portion of the third line between the two zones represents the common iliac, and that portion below the lower zone, the external iliac. The right common iliac is about 5 cm. (2 in.) in length, and the left about 4.5 cm. (1¾ in.).

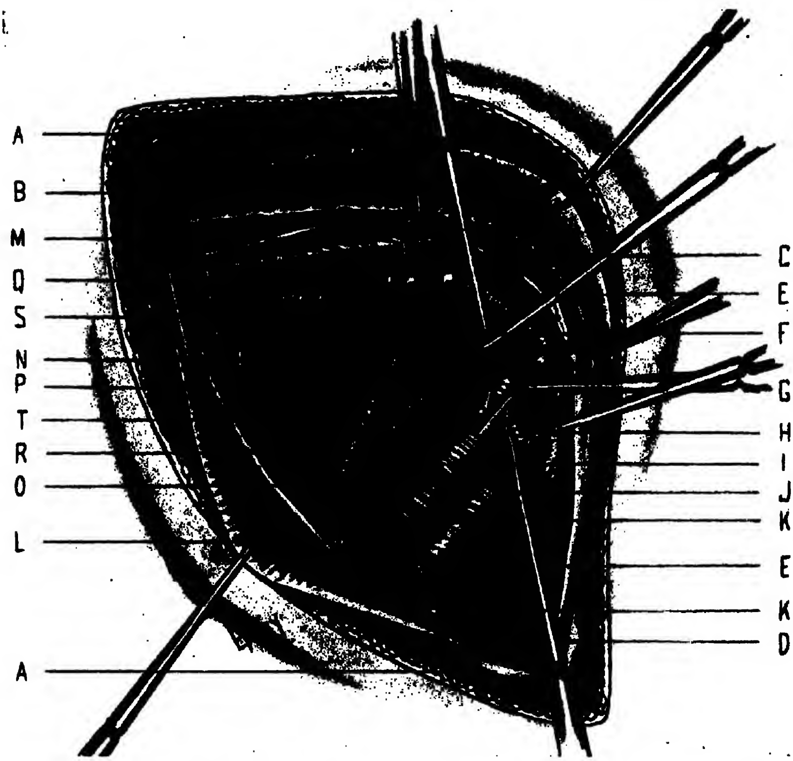

FIG. 268.—LIGATION OF RIGHT COMMON AND INTERNAL ILIACS, RETROPERITONEALLY.

A, A, External oblique muscle and aponeurosis; B, internal oblique; C, transversalis; D, conjoint tendon; E, E, peritoneum, retracted; F, uretor, retracted; G, common iliac artery (sheath incised); H, internal iliac artery (sheath incised); I, external iliac artery; J, external and internal iliac veins; K, K, deep epigastric artery; L, deep circumflex iliac artery; N, iliolumbar artery; O, spermatic artery; P, anterior crural nerve; Q, ilio-inguinal nerve; R, genitocrural nerve; S, external cutaneous nerve; T, iliac fascia; M, lumbar artery and iliohypogastric (or dorsal) nerve.

Ligation of the Common Iliac Artery by the Retroperitoneal Method.—The patient is supine or slightly turned to one side. The intestines are more easily displaced from the field of operation if the patient be in the Trendelenburg position. The surgeon stands upon the side of operation. The assistant is opposite.

The landmarks are the line of the external iliac artery (v. s.), Poupart's ligament, the anterior superior spine of the ilium, and the eleventh rib.

The incision is begun as for the exposure of the external iliac (page 711) and continued in the cleavage line of the external oblique as far upward toward the eleventh rib as necessary to furnish sufficient room (Fig. 267, B).

The steps of the operation are identical with those for exposure of the external iliac (page 711), with an extension upward, in the present operation, of the separation of the fibers of the external oblique and a division of the fibers of the internal oblique and transversalis as far up toward the eleventh rib as necessary, the incision of the two latter muscles corresponding in direction with the separation of the fibers of the external oblique (Fig. 268). In this higher part of the wound the last dorsal and other dorsal nerves are apt to be encountered between the internal oblique and transversalis and are to be carefully preserved. The deep circumflex iliac artery and the lumbar arteries are apt to be met here above the crest of the ilium. Having divided the transversalis fascia and separated the peritoneum from the iliac fascia (which overlies the iliacus muscle), detaching it downward and backward to the psoas muscle, and then upward to the sacral promontory, the structures in the floor of the iliac fossa are exposed. The external iliac artery is first found, and this is followed up to the common iliac, guarding the deep epigastric. The genitocrural, external cutaneous, and anterior crural nerves, branch of the iliolumbar, and the spermatic arteries cross this area. The ureter crosses either the common iliac or the external iliac obliquely opposite the first piece of the sacrum, having the ileum in front of it on the right and the sigmoid flexure of the colon in front of it on the left, but in the peeling back of the peritoneum the ureter usually adheres to the peritoneum, and is thus removed from the area of operation without trouble. The artery having been reached and bared of peritoneum, the needle is passed from the iliac vein.

The line of incision may begin further to the outer side of the external iliac than for the typical operation upon that artery, though that vessel is then a little less easily encountered. As to a choice between the extraperitoneal and intraperitoneal operation, the former is to be preferred wherever the relations of the parts are not too much disturbed by disease or injury. The common iliac artery may also be ligated by the transperitoneal route. The steps are practically the same as for the transperitoneal ligation of the abdominal aorta, though somewhat less extensive, and with the slight modifications necessitated by the anatomy of the parts (Fig. 267, C). Especial care is taken to recognize the position of the ureter before incising the peritoneum.

Ligation of the Internal Iliac Artery.—The indications for the ligation of this artery are gluteal and sciatic aneurism, hemorrhage, and to cause atrophy of the prostate gland.

The vessel is secured midway between its origin and its bifurcation.

The line of the artery is given under that of the common iliac.

The vessel may be secured by either the retroperitoneal or transperitoneal route.

Ligation by the Retroperitoneal Route.—The position, landmarks, and incision are the same as for the retroperitoneal ligation of the external iliac, which, having been exposed, is followed up to the bifurcation of the common iliac (Fig. 267, B, and Fig. 269).

Ligation by the Transperitoneal Route.—The position, landmarks, incision, and operation are the same as for the transperitoneal ligation of the abdominal aorta, with the modifications necessitated by the anatomy of the parts (Fig. 267, C and page 704). Recognize the position of the ureter before incising the peritoneum.

Ligation of the Sciatic Branch of the Internal Iliac.—The indications for ligation are wounds and hemorrhage.

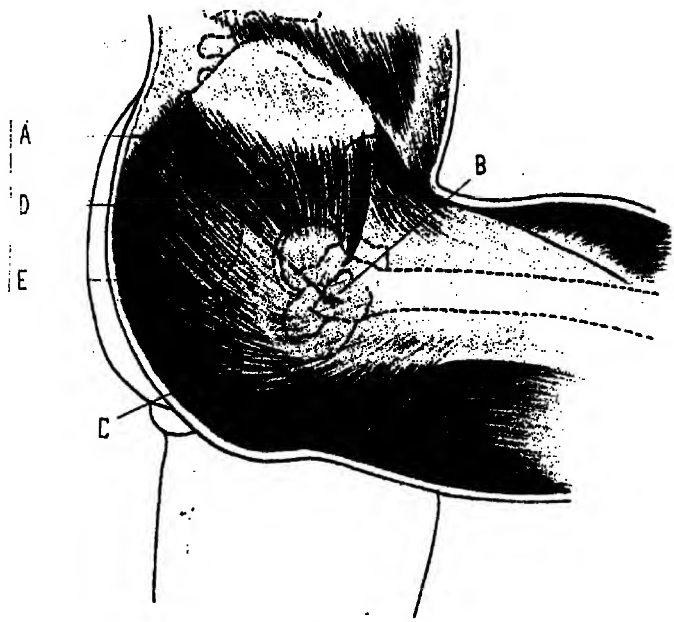

FIG. 269.—INCISIONS FOR LIGATIONS ABOUT THE BUTTOCK.

A, Posterior superior iliac spine; B, great trochanter; C, tuberosity of ischium; D, incision for exposure of gluteal branch of internal iliac at its emergence from upper part of great sacrosciatic notch; E, for exposure of sciatic and internal pudic branches of internal iliac at their emergence from lower part of great sacrosciatic notch.

The site for ligation is at the emergence of the vessel onto the gluteal region, just below the pyriformis muscle.

The line of the artery is gotten in the following manner—having rotated the thigh inward and slightly flexed it, draw a line from the posterior superior iliac spine to the outer border of the tuberosity of the ischium. The point on this line, at the junction of its middle and lower thirds, will represent the site at which the sciatic and pudic arteries emerge from the lower part of the sciatic foramen upon the gluteal region (Fig. 269, A, C, E).

Ligation of the Sciatic upon the Buttock.—The patient lies upon the uninvolved side, rolled nearly onto the chest, with the knee

flexed and thigh rotated inward. The surgeon is on the side of the operation, the assistant standing opposite.

The landmarks are the posterior superior iliac spine and the tuberosity of the ischium.

Having drawn the line of the artery, as given above, make an incision about 10 cm. (4 in.) in length, obliquely across this line, in the direction of the fibers of the gluteus maximus (which run from above and behind, downward and forward), with its center corresponding to the junction of the middle and lower thirds of the line (Fig. 269, E).

Having incised the skin and thick fatty areolar tissue, divide the fibers of the gluteus maximus in their cleavage line (Fig. 270, F). Retract the separated margins of this muscle upward and downward respectively. Expose the lower margin of the pyriformis muscle. Follow the lesser sacrosciatic ligament to the spine of the ischium,

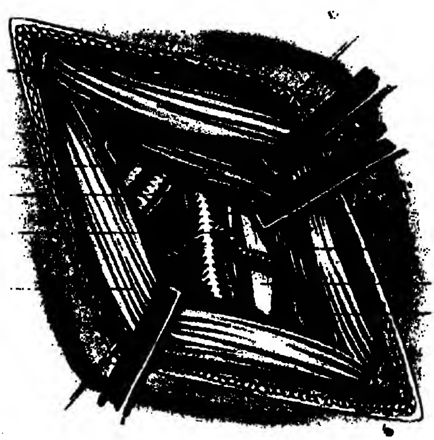

FIG. 270.—LIGATION OF RIGHT INTERNAL PUDIC AND SCIATIC ARTERIES UPON THE BUTTOCK, BELOW THE PYRIFORMIS.

A, A, Gluteus maximus (incised and retracted); B, pyriformis (lower border retracted upward); C, obturator internus, with gemellus superior and inferior above and below; D, pudic artery and venæ comites; E, internal pudic nerve; F, sciatic artery and venæ comites; G, small sciatic nerve; H, great sciatic nerve.

when the sciatic artery will be found emerging from beneath the pyriformis muscle, passing out of the pelvis above the spine of the ischium, and the lesser sacrosciatic ligament attached to it and lying posterior and external to the pudic artery.

Ligation of the Internal Pudic Artery.—Wounds and hemorrhage are the chief indications for ligation of this vessel.

The artery may be tied over the spine of the ischium or in the perineum (Figs. 269, 270).

The line of the artery is indicated under Ligation of the Sciatic Artery (page 708).

The position, landmarks, incision, and operation are the same as for the ligation of the sciatic branch of the internal iliac upon the buttock, the arteries lying side by side at their exit from the pelvis, below the lower border of the pyriformis (Fig. 268, E, and Fig. 269, D).

Ligation of the Gluteal Artery.—The indications for ligation are wounds and aneurism.

The site for ligation is at the emergence from the sciatic notch, at the upper border of the pyriformis muscle.

To find the line of the artery, having rotated inward and slightly flexed the thigh, draw a line from the posterior superior iliac spine to the top of the great trochanter. A point on this line at the junction of the upper and middle thirds will correspond with the emergence of the gluteal artery from the sciatic notch (Fig. 268, A, B, D).

Ligation of the Gluteal Artery Upon the Buttock.—The patient lies on the involved side, rolled nearly onto the chest, with knee flexed and the thigh rotated inward. The surgeon is on the side of the operation.

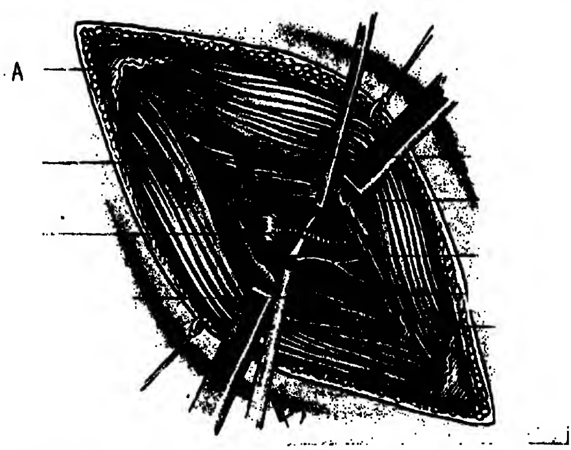

FIG. 271.—LIGATION OF RIGHT GLUTEAL ARTERY UPON THE BUTTOCK, ABOVE THE PYRIFORMIS.

A, Deep fascia over gluteus maximus; B, B, gluteus maximus, incised and retracted; C, gluteus medius (retracted upward); D, pyriformis (retracted downward); E, fascia between gluteus maximus and gluteus medius and pyriformis; F, gluteal artery and venæ comites; G, superior gluteal nerve and branches; H, gluteus minimus.

The landmarks are the posterior superior iliac spine and the top of the great trochanter.

The incision is about 10 cm. (4 in.) in length, and is placed along the line given above, with its center at the junction of its upper and middle thirds, which will be over the site at which the gluteal artery leaves the sciatic notch (Fig. 268, D).

After dividing the skin and superficial fascia, some superficial nerves and the fascia of the gluteus maximus, the muscle itself is met, its fibers running parallel with the skin incision (Fig. 271). Incise the muscle-fibers of the gluteus maximus along their cleavage line. Having passed through the thickness of the gluteus maximus, a branch of the gluteal artery will generally lead to the interval between the gluteus medius and pyriformis (which otherwise is sought without this guide). Having divided the fascia over the lower border of the gluteus medius, separate these muscles by retractors and expose the upper margin of the sciatic notch by passing the finger under the lower border of the

gluteus medius, and through the upper portion of the sciatic notch, between the lower border of the gluteus medius and the upper border of the pyriformis, emerge the gluteal artery, vein, and superior gluteal nerve.

Ligation of the External Iliac Artery.—The indications for ligation are wounds, secondary hemorrhage, femoral or iliofemoral aneurisms, to arrest malignant growths, elephantiasis arabum, and as a distal ligation in aneurism of the common iliac.

The site of the ligation is proximal to the deep epigastric and deep circumflex iliac branches.

The line of the artery is indicated under the Common Iliac, page 705.

Ligation of the External Iliac by the Retroperitoneal Route.—The patient lies in the supine position, near the edge of the table. The

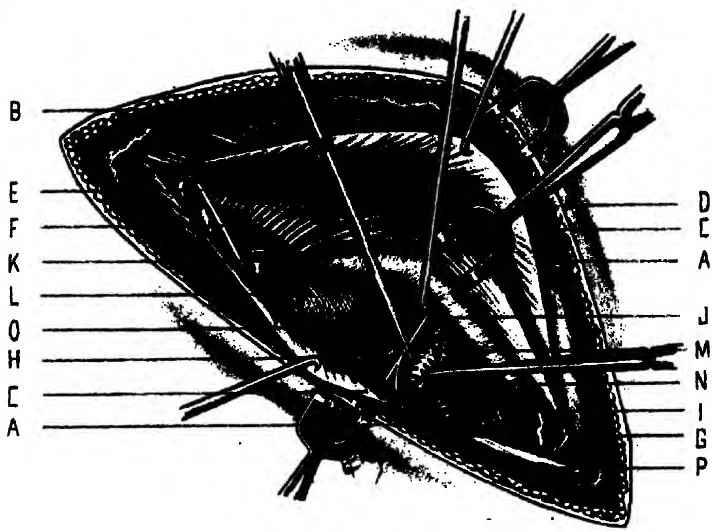

FIG. 272.—LIGATION OF RIGHT EXTERNAL ILIAC, RETROPERITONEALLY THROUGH OBLIQUE INCISION PARALLEL WITH POUPART'S LIGAMENT.

A, A, Superficial epigastric artery; B, external oblique muscle; C, C, external oblique aponeurosis; D, internal oblique; E, ilio-inguinal nerve; F, transversalis muscle; G, conjoint tendon; H, deep circumflex iliac artery and accompanying vein; I, deep epigastric artery and venæ comites; J, genito-crural nerve; K, peritoneum (peeled back and retracted upward); L, iliac fascia; M, external iliac artery (its sheath incised); N, external iliac vein; O, anterior crural nerve (seen through fascia); P, Poupart's ligament.

surgeon stands on the side of the operation. The landmarks are Poupart's ligament, the anterior superior iliac spine, and the line of the artery. The incision begins over the external iliac artery, about 1.3 cm. (½ in.) above Poupart's ligament, and passes upward and outward, parallel with the ligament, to the anterior superior iliac spine, and is prolonged upward as far as necessary in the cleavage line of the external oblique (Fig. 267, D). Having incised the skin and superficial fascia, together with, possibly, the superficial epigastric and the branches of the superficial circumflex iliac, with their veins, ligating where necessary, expose the aponeurosis of the external oblique (Fig. 272). Divide this aponeurosis in its cleavage line without cutting its fibers, and continue this division or separation in the cleavage line

as far toward or beyond the anterior superior iliac spine as indicated to give free room for manipulation. Having retracted the cut edges of the external oblique well apart, separate from the outer half of Poupart's ligament the attachment of the internal oblique. Carefully retract the cut edges of the internal oblique, being on the watch for branches of the iliohypogastric and ilio-inguinal nerves between the internal oblique and transversalis, and, if encountered, carefully displace them above or below, but avoid cutting them. If necessary to gain more room, the internal oblique is to be carefully incised in the line of the separation of the external oblique as far as the upper limit of the separation of the fibers of the latter muscle. Having incised the internal oblique and protected the nerves encountered, detach the transversalis from the outer third of Poupart's ligament, and as far beyond as necessary, incising its fibers transversely to their direction, but in the direction of the division of the internal oblique. After dividing the transversalis, guard the deep circumflex iliac artery and vein and the genitocrural nerve, both lying between the transversalis fascia and peritoneum. Having now separated the fibers of the aponeurosis of the external oblique, and divided the fibers of the internal oblique and transversalis in the same line as the separation of the external oblique aponeurosis, and having safeguarded the important nerve encountered, the fascia transversalis is then exposed and is divided over the artery in a transverse direction, corresponding with the preceding incision lines and separation. The artery is here clearly defined, and the deep epigastric, the main source of collateral circulation, is carefully guarded. As soon as the artery is clearly located, the subperitoneal tissue about the vessel is carefully opened up and the artery well exposed as well as the deep epigastric, for the purpose of guarding it. The peritoneum is then pushed and rolled backward and upward from the vessel with the fingers and held out of the way by retractors. When sufficiently exposed, the sheath of the artery is opened and the needle passes from the vein on the inner side, guarding the anterior crural nerve on the outer side. The ligature should be about 3 cm. (1¼ in.) above Poupart's ligament. In concluding the operation the cut edges of the transversalis are united by catgut sutures to their line of severance from Poupart's ligament, and as far beyond as they may have been divided. The cut edges of the internal oblique are similarly sutured to their former attachment to Poupart's ligament, and to their opposite cut margin as far as divided. And, finally, the separated margins of the external oblique are united by buried gut sutures. The skin wound is then closed.

The incision for exposure may, if thought necessary, begin about 3 cm. (1¼ in.) to the outer side of the spine of the os pubis, being thus begun well to the inner side of the artery, as in the modified Astley Cooper operation.

Ligation of the External Iliac by the Transperitoneal Route.—The position is the same as in the extraperitoneal operation, or the patient may be in the Trendelenburg position.

The landmarks are the same as far as the extraperitoneal exposure.

The incision may be made in one of three sites: as an intramuscular incision, placed over the site of the artery to be tied (Fig. 267, F); as a vertical incision in the linea semilunaris (Fig. 267, E); or as a vertical incision in the linea alba (Fig. 267, C).

The steps of the operation and the manipulation to expose the site of ligation are, practically, similar to those in the transperitoneal exposure of the common iliac or the internal iliac.

Ligation of the Femoral Artery.—The indications for ligation are the same as for ligation of the external iliac (p. 711).

The sites for ligation are the common femoral at the base of Scarpa's triangle, rare (on account of proximity of large vessels); the superficial

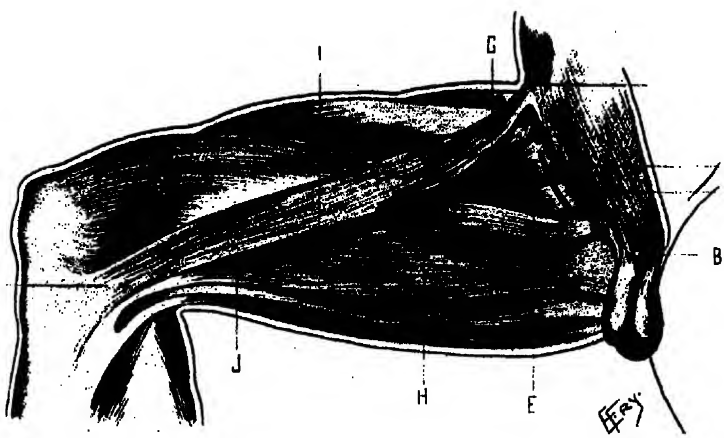

FIG. 273.—INCISIONS FOR LIGATION OF CHIEF ARTERIES OF THIGH.

A, Anterior superior iliac spine; B, symphysis pubis; C, adductor tubercle; D, midpoint between anterior superior iliac spine and symphysis pubis; E, ligation of common femoral at base of Scarpa's triangle, by incision parallel with artery; F, same, by incision parallel with and just below Poupart's ligament; G, of profunda femoris, near origin; H, of superficial femoral at apex of Scarpa's triangle; I, of superficial femoral in Hunter's canal; J, of popliteal in upper part of popliteal space, from inner side of thigh.

femoral at the apex of Scarpa's triangle, the operation of election; and the superficial femoral in Hunter's canal, not common (Fig. 273).

The line of the artery is determined in the following manner: the hip is slightly flexed and the thigh abducted and rotated outward. The line is from a point midway between the anterior superior iliac spine and symphysis pubis, to the abductor tubercle of internal femoral condyle (Fig. 273, D, C). When the thigh is in normal position and parallel with its fellow, the line is then from a point midway between the anterior superior iliac spine and symphysis pubis to inner border of the patella. A few observations may be here made. A short common femoral is more frequent than a long one. The apex of Scarpa's triangle is from 7.5 cm. to 9 cm. (3 to 3½ in.) below Poupart's ligament. The profunda femoris arises about 4 cm. (1½ in.) below Poupart's ligament. At the groin the femoral artery and vein are on the

same plane; at the apex of Scarpa's triangle the vein is posterior, in the middle of Hunter's canal the vein is posterior and slightly external, at the lower part of Hunter's canal the vein is external. The order of the vessels at the apex of Scarpa's triangle, from before backward, is the femoral artery, femoral vein, profunda vein, and profunda artery.

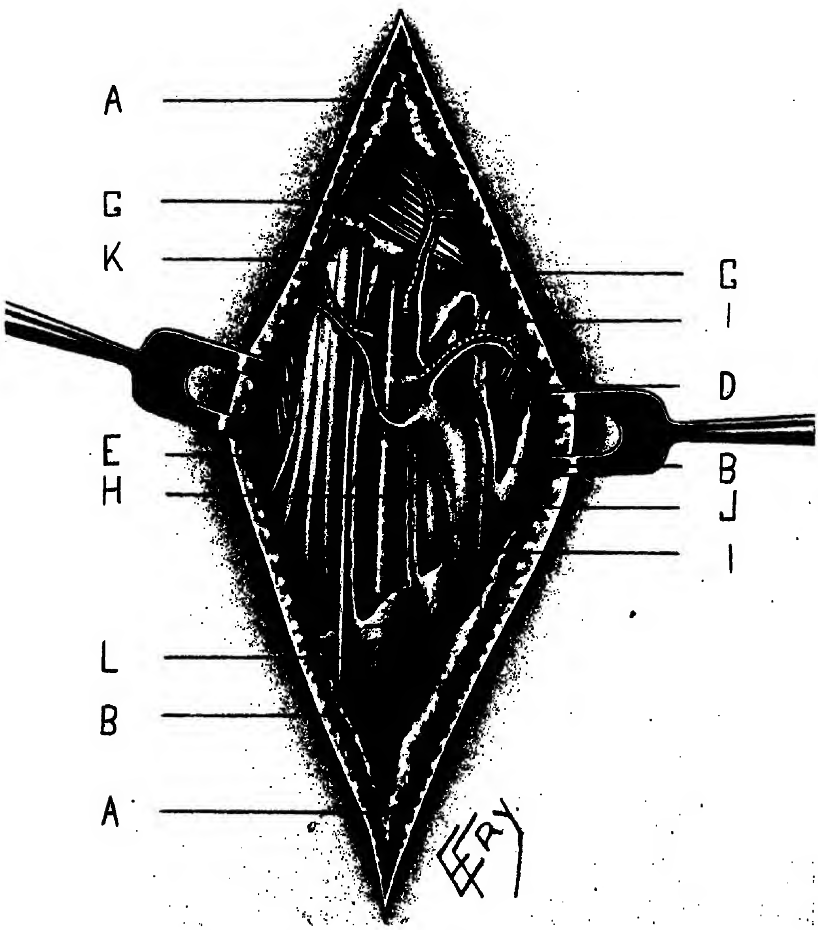

FIG. 274.—LIGATION OF RIGHT COMMON FEMORAL AT BASE OF SCARPA'S TRIANGLE.

A, A, Superficial fascia; B, B, fascia lata; D, pectineus; E, psoas; G, G, Poupart's ligament and external oblique; H, common femoral artery, with superficial epigastric, external pudic, and circumflex iliac branches; I, I, femoral vein; J, internal saphenous, with superficial epigastric external pudic, and circumflex iliac veins; K, anterior crural nerve; L, crural branch of genito-crural.

The line approximately representing the course of the long saphenous vein is one running from a point about 2 cm. (¾ in.) internal to the midpoint between the anterior superior iliac spine and symphysis pubis, to the posterior border of the sartorius muscle at the femoral condyle.

Ligation of the Common Femoral at the Base of Scarpa's Triangle by an Incision Parallel with Artery.—The patient lies in the supine position, the hip slightly flexed, the thigh abducted and rotated outward, and the knee bent and lying upon its outer aspect.

The surgeon stands on the side of the operated limb, cutting from above downward on the right, and vice versâ.

The landmark is the line of the artery.

The incision is about 5 cm. (2 in.) long, beginning just a little above Poupart's ligament and extending downward in the line of the artery (Fig. 273, E).

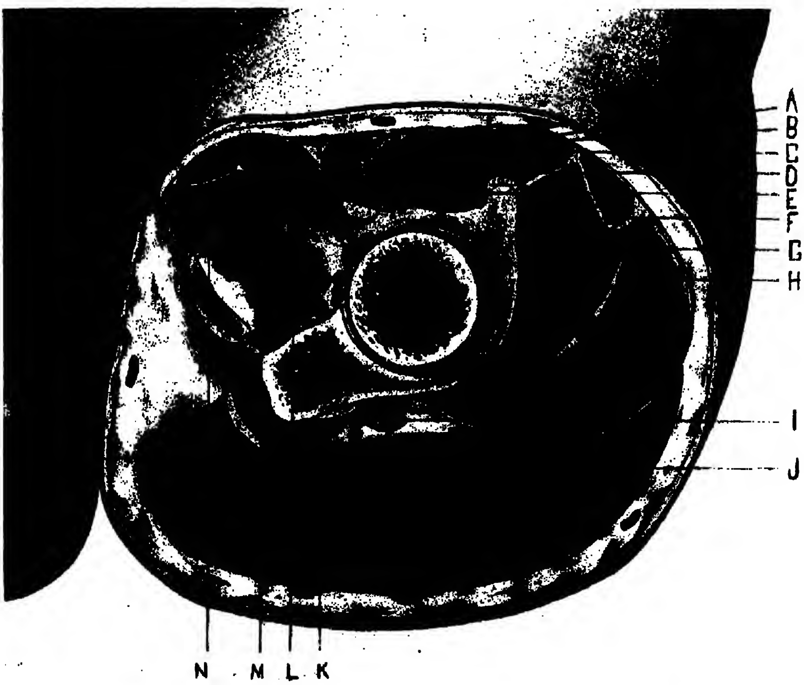

Fig. 275.—Cross-section of the Left Thigh Through the Head of the Femur. (The skin relations of this section erroneously represent a lower level.)

A, Iliacus; B, sartorius; C, femoral artery, vein, and crural nerve; D, pectineus; E, psoas; F, tensor vaginæ femoris; G, gluteus minimus; H, gluteus medius; I, great sciatic artery, vein, and nerve; J, gluteus maximus; K, obturator internus; L, obturator externus; M, adductor brevis; N, adductor longus. (Cross-section from Braune.)

Incise the skin and the superficial fascia. Avoid the lymphatic glands, also the superficial circumflex iliac, the superficial epigastric, and the superficial external pudic arteries and veins. Divide the iliac portion of the fascia lata (Fig. 274). Avoid the crural branch of the genitocrural nerve on the femoral sheath, a little external to the artery. Expose and open the sheath, guarding the femoral vein, which lies immediately to the inner side of the artery and within the sheath, and the anterior crural nerve lying further to the outer side of the artery and outside of the sheath (Fig. 275). Pass the needle

from the vein. It may be said that the ligation of the femoral at the base of Scarpa's triangle is rarely done, owing to the number and nearness of the branches, except in such cases as wounds and to control hemorrhage at the hip-joint, or for temporary control in operating about the thigh. Where not otherwise indicated, the ligation of the external iliac is the better operation. The artery may also be exposed at this site by an incision parallel with and about 6 mm. (¼ in.) below the middle third of Poupart's ligament (Fig. 273, F).

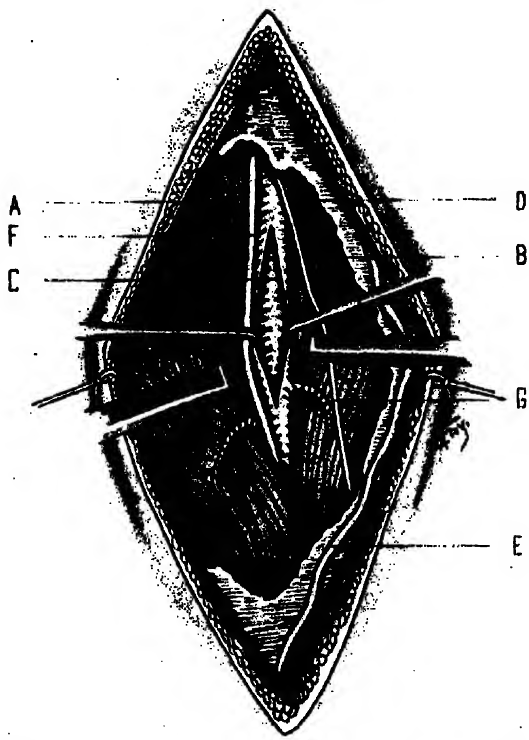

Fig. 276.—Ligation of Right Femoral at Apex of Scarpa's Triangle.

A, Sartorius; B, adductor longus; C, femoral artery and muscular branches, with its sheath incised and retracted; D, femoral vein; E, branch of internal saphenous vein; F, long saphenous nerve; G, internal cutaneous nerve.

Ligation of the Superficial Femoral at the Apex of Scarpa's Triangle.—The position and landmarks are the same as in the operation for the exposure at the base of Scarpa's triangle.

The incision is made about 7.5 cm. (3 in.) in length in the line of the artery, with its center over the apex of Scarpa's triangle—that is, about 7.5 cm. (3 in.) below Poupart's ligament (Fig. 273, H).

Incise the skin and superficial fascia. Draw aside or ligate the branches of the internal saphenous vein (Fig. 276). Divide the fascia lata. Identify the inner margin of the sartorius (its fibers running downward and inward) and retract it outward. Open up the groove between the sartorius and adductor longus (the fibers of the latter

running directly downward, or downward and outward), and retract the adductor longus internally if necessary (Fig. 277).

The internal cutaneous nerve and long saphenous nerve are encountered anteriorly to the artery and are to be displaced to one side.

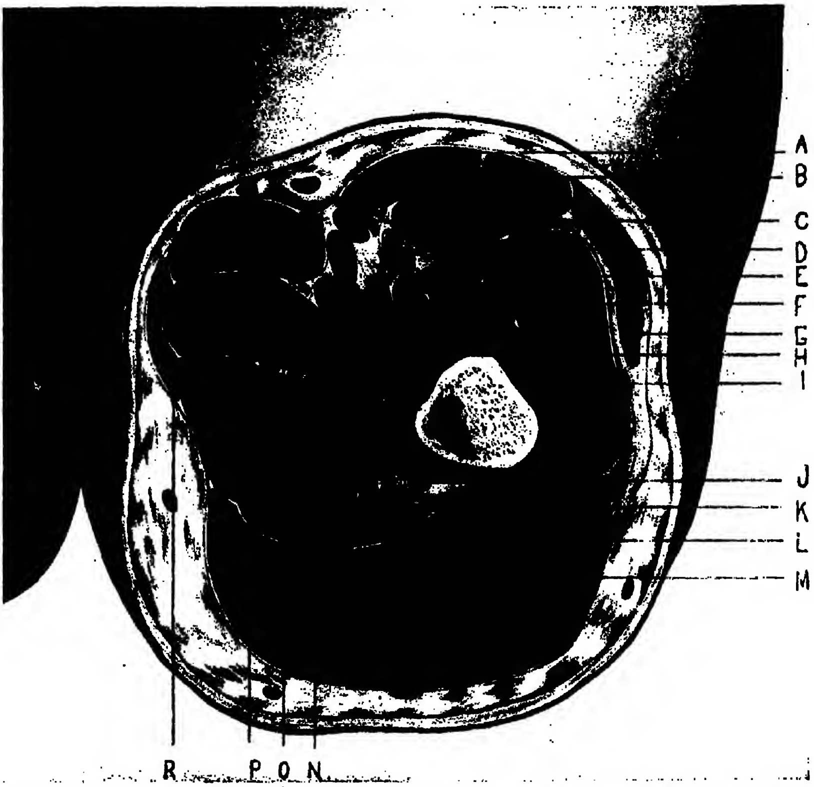

Fig. 277.—Cross-section Through the Left Thigh at the Level of the Lesser Trochanter. A, Sartorius; B, rectus; C, superficial femoral artery, vein, and anterior crural nerve; D, profunda femoral artery and vein; E, crureus; F, iliacus; G, tensor vaginæ femoris; H, pectineus; I, vastus externus; J, sciatic nerve and artery; K, semimembranosus; L, biceps and semitendinosus; M, gluteus maximus; N, adductor magnus; O, adductor brevis; P, adductor longus; R, gracilis. (Cross-section modified from Braune.)

Clearly identify the femoral sheath and incise it, guarding the femoral vein which lies posteriorly and internally to the artery. Pass the needle from the vein.

Ligation of the Superficial Femoral in Hunter's Canal.—The position of the patient is the same as for the ligation at the base of Scarpa's triangle.

The landmark is the line of the artery.

The incision is from 7.5 to 9 cm. (3 to 3½ in.), in the line of the artery, over the middle third of the thigh (Fig. 273, I).

Incise the skin and superficial fascia. The anterior branch of the internal cutaneous nerve, to the outer side, and the long saphenous vein to the inner side, are likely to be encountered. Divide the fascia

lata. Expose the outer edge of the sartorius (its fibers running downward and inward) and retract inward from its position over the roof of Hunter's canal (Fig. 278). Hunter's canal is thereby exposed in the interval between the vastus internus and adductor magnus (the fibers of the latter running obliquely downward and outward). The nerve to the vastus internus may be here exposed. Incise the roof of the canal, when the internal saphenous nerve is found between the aponeu-

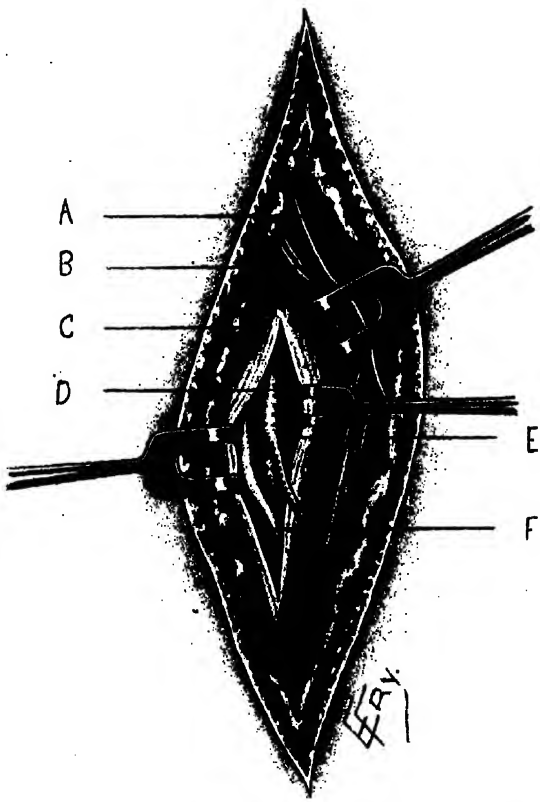

FIG. 278.—LIGATION OF THE RIGHT FEMORAL ARTERY IN HUNTER'S CANAL.
A, Internal cutaneous nerve; B, sartorius; C, Hunter's canal, the roof incised; D, femoral artery; E, femoral vein; F, internal saphenous nerve.

rotic roof and the sheath of the vessels, running from without inward (Fig. 279). Open the sheath and pass the ligature from the vein. Guard against taking the vastus for the sartorius, the fibers of the former running downward and outward.

Ligation of the Popliteal Artery.—The indications for the ligation of this vessel for other conditions than those of wounds and aneurisms are rare.

The artery may be ligated either in its upper or lower part, the vessel being tied with difficulty in its middle, owing to its depth and relations (Figs. 273, J, and 280, F and G).

The line of the artery extends from the outer border of the semimembranosus, at the junction of the middle and lower thirds of the thigh, obliquely down to the middle of the popliteal space, directly posterior to the knee-joint (for the upper part of the artery), and from the midpoint of the popliteal space vertically down to the level of the lower border of the tubercle of the tibia (for the lower part of the artery) (Fig. 280, A, B, C).

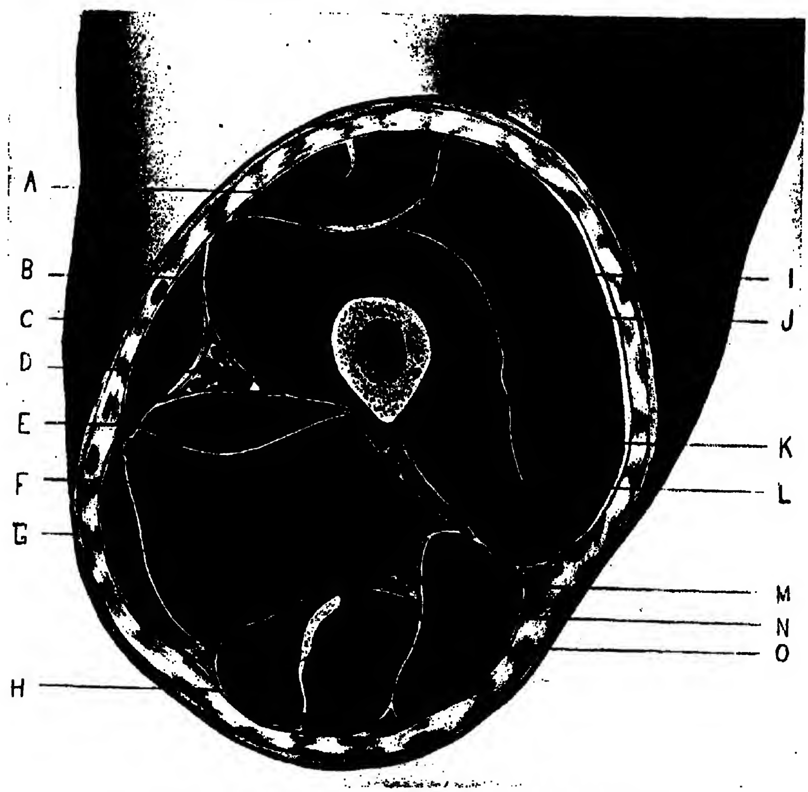

FIG. 279.—CROSS-SECTION THROUGH THE MIDDLE OF THE LEFT THIGH.

A, Rectus muscle; B, vastus internus; C, sartorius; D, superficial femoral artery, vein, and saphenous nerve; E, adductor longus; F, adductor magnus; G, gracilis; H, semimembranosus; I, vastus externus; J, descending branch of external circumflex; K, terminal branch of profunda femoris; L, crureus; M, great sciatic nerve and arteria comes nervi ischiadici; N, biceps; O, semitendinosus. (Cross-section modified from Braune.)

Ligation of the Popliteal Artery in the Upper Part of the Popliteal Space from the Inner Side (Jobert's Operation).—The patient is supine, the thigh slightly flexed and fully abducted and rotated outward, with the knee at a right angle and resting on its external aspect. The surgeon stands on the outside, cutting downward on the right and upward on the left (or he may stand on the inner side of the left and cut downward).

The landmark is the tendon of the adductor magnus.

An incision about 7.5 cm. (3 in.) in length, beginning opposite the junction of the middle and lower thirds of the thigh, is made, running

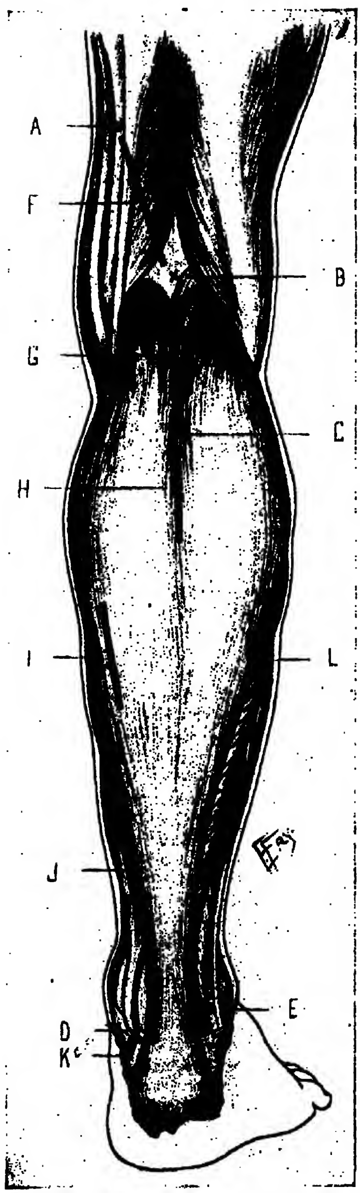

FIG. 280.—LIGATION OF POPLITEAL, POSTERIOR TIBIAL, AND PERONEAL ARTERIES.

A, Outer border of semimembranosus (at junction of middle and lower thirds of thigh); B, middle of popliteal space; C, center of posterior aspect of leg on level with tibial tubercle; D, point midway between convexity of heel and tip of internal malleolus; E, midpoint between outer border of tendo Achillis and tip of external malleolus; F, incision for popliteal artery in upper part of popliteal space, from behind; G, same, in lower part of popliteal space; H, of posterior tibial in its upper third; I, same, in its middle third; J, same, in its lower third; K, same, behind internal malleolus; L, incision for peroneal in middle of leg.

parallel with and immediately posterior to the tendon of the adductor magnus (which is inserted into the adductor tubercle on the internal condyle of the femur) (Fig. 273, J).

Incise the skin and superficial fascia. Avoid the anterior branch of the internal cutaneous nerve (Fig. 281). Divide the deep fascia. Expose the anterior edge of the sartorius and retract it backward, together with the internal saphenous vein, if in view (the internal saphenous nerve being beneath the sartorius, out of view). Having thoroughly divided the deep fascia, the adductor magnus tendon is identified and drawn forward, then the semimembranosus is identified and drawn backward, and the artery is then sought between these two structures, near the bone and in considerable fatty areolar tissue.

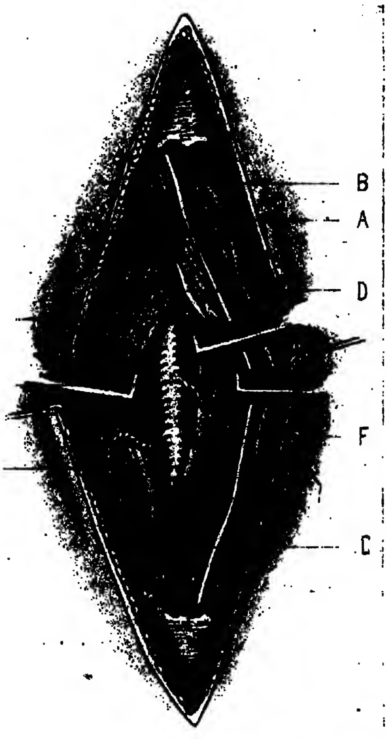

FIG. 281.—LIGATION OF UPPER PART OF RIGHT POPLITEAL FROM INNER SIDE OF THIGH.
A, Anterior branch of internal cutaneous nerve; B, internal saphenous vein; C, sartorius (its anterior border retracted posteriorly); D, internal saphenous nerve (mainly under sartorius, out of sight); E, adductor magnus (drawn anteriorly); F, semimembranosus (drawn posteriorly); G, popliteal artery; H, popliteal vein (below and external to artery).

Both the popliteal vein and nerve lie on a plane posterior to the artery, and are generally not brought to view.

Ligation of the Popliteal Artery in the Lower Part of the Popliteal Space by a Posterior Median Incision.—The patient lies as nearly prone as feasible, resting on the side of the shoulder and chest with the limb extended. The surgeon stands to the outer side of the left limb, cutting downward, and to the outer side of the right limb, cutting upward (or inside of the right limb, cutting downward). The landmarks are the boundaries of the popliteal space (the biceps

above and the plantaris and outer head of the gastrocnemius below, forming the outer boundary, and the semimembranosus and semitendinosus above and the inner head of the gastrocnemius below, forming the inner boundary).

The incision is about 9 cm. (3½ in.) in length, beginning at the middle of the popliteal space (on a level with the knee-joint) and passing downward between the two heads of the gastrocnemius (Fig. 280, G).

Incise the skin and superficial fascia. Avoid the external saphenous vein and external saphenous nerve in the outer aspect of the wound or the

FIG. 282.—LIGATION OF RIGHT POPLITEAL AT LOWER PART OF POPLITEAL SPACE.

A, Inner head of gastrocnemius (retracted inward); B, outer head of gastrocnemius (drawn outward); C, plantaris; D, external saphenous vein; E, communicans poplitei nerve; F, internal popliteal nerve (drawn inward); G, popliteal vein (drawn inward); H, popliteal artery and muscular branches; I, popliteus muscle.

communicans poplitei nerve, which helps form the external saphenous nerve (Fig. 282). Divide the deep fascia. Expose the inner and outer heads of the gastrocnemius with the sural arteries going to them, and retract these and the plantaris muscle to their respective sides. Muscular branches of the internal popliteal nerve may be met with here and perhaps the posterior tibial nerve. The external saphenous vein is the guide to the popliteal vessels. The internal popliteal nerve is found the most superficial of the three important structures, the popliteal vein next (both crossing to the inner side, toward which side

they are further retracted) and the artery deepest of all, near the bone and in much fatty areolar tissue. The needle is passed from the

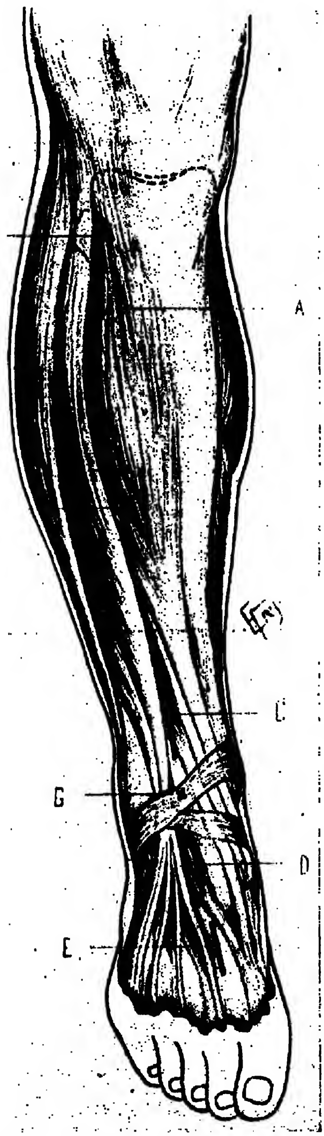

FIG. 283.—INCISIONS FOR LIGATION OF ANTERIOR TIBIAL AND DORSALIS PEDIS ARTERIES.

A, Incision for upper third of anterior tibial; B, for middle third of anterior tibial; C, for lower third of anterior tibial; D, for dorsalis pedis just below ankle-joint; E, for dorsalis pedis in first interosseous space; F, inner side of head of fibula; G, midpoint between two malleoli.

side of the vein, flexure of the knee aiding during this stage. A continuation upward of the above incision would amount to a ligation of the popliteal artery in the middle of the popliteal space.

Ligation of the Anterior Tibial Artery.—The indications for ligation are wounds (of the anterior tibial or in the foot) and aneurisms.

The sites of ligation are the upper and middle thirds—rarely, except in wounds—and the lower third, the most frequent site (Fig. 283).

The line of the artery extends from the inner side of the head of the fibula to the center of the line between the malleoli. According to Kocher, the line is given as extending from midway between the external surface of the head of the fibula and the center of the tubercle of the tibia to the same point below. The artery passes through the interosseous membrane about 3 cm. (1¼ in.) below the level of the head of the fibula.

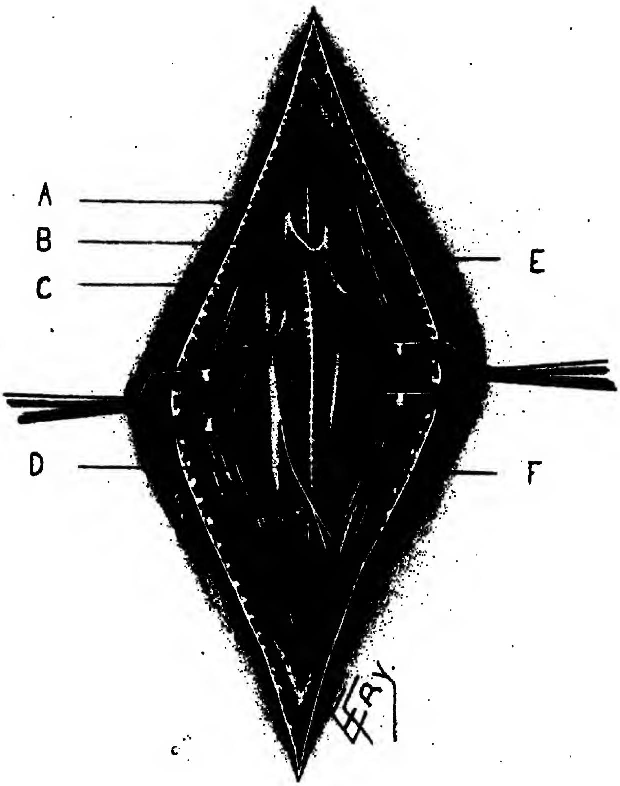

Fig. 284.—Ligation of the Upper Third of the Right Anterior Tibial Artery.
A, Anterior tibial artery; B, venæ comites; C, anterior tibial nerve; D, extensor communis digitorum; E, branch of internal saphenous vein; F, tibialis anticus muscle.

Ligation of the Anterior Tibial Artery in Its Upper Third.—The patient is supine, with the leg extended and rotated inward. The surgeon is on the outer side, cutting from above downward on the right, and vice versâ.

The landmark is the line of the artery.

An incision about 7.5 cm. (3 in.) in length is made in the line of the artery, beginning about 2.5 cm. (1 in.) below the head of the fibula (Fig. 283, A).

Incise the skin and superficial and deep fascia. Define the gap between the tibialis anticus, internally, and the extensor longus digitorum, externally, and retract these structures to their respective sides (Fig. 284). Open up this interval, flexing the foot to relax the parts. Aim to reach the external aspect of the tibia, covered by the tibialis anticus, and when reached, follow down to the interosseous membrane,

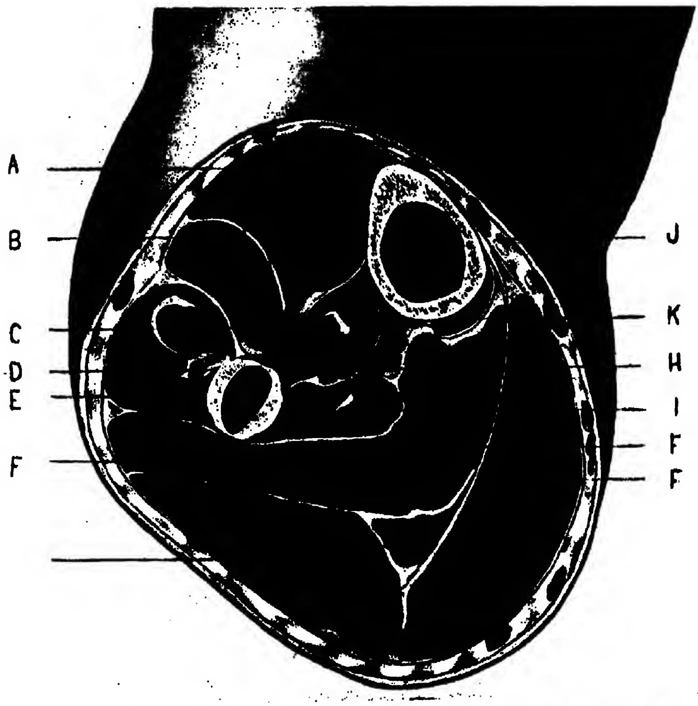

FIG. 285.—CROSS-SECTION THROUGH THE UPPER THIRD OF THE RIGHT LEG.
A, Tibialis anticus; B, extensor longus digitorum; C, anterior tibial vessels and nerve; D, musculocutaneous nerve; E, peroneus longus; F, F, F, F, gastrocnemius; H, posterior tibial vessels and nerve; I, soleus; J, internal saphenous vein and nerve; K, popliteus. (Cross-section modified from Braune.)

upon which the artery will be found (Fig. 285). The two venæ comites lie in very close contact, in front of and behind the artery. The anterior tibial nerve may not yet have reached the outer side of the artery. If the venæ comites be not separable, include them in the ligature. In conclusion, it may be said that the interval between the tibialis anticus and extensor longus digitorum is the key to the situation and is rather hard to find. The outer edge of the tibialis anticus often overlaps the extensor longus digitorum. And also one may get into the septum between the extensor longus digitorum and peroneus longus and work down toward the fibula. Guides to the proper intermuscular gap,

accessory to the sensation of touch, are the "white line" (sometimes visible) and a small artery leading to the anterior tibial.

Ligation of the Anterior Tibial Artery in Its Lower Third.—The position of the patient is the same as for the above operation, except that the foot is not rotated inward.

The landmark is the line of the artery.

An incision from 5 to 7.5 cm. (2 to 3 in.) in length is made, with its center over the center of the lower third of the leg (Fig. 283, C).

The skin and fascia are incised. Clearly identify the tendon of the tibialis anticus. Divide the upper part of the superior band of the

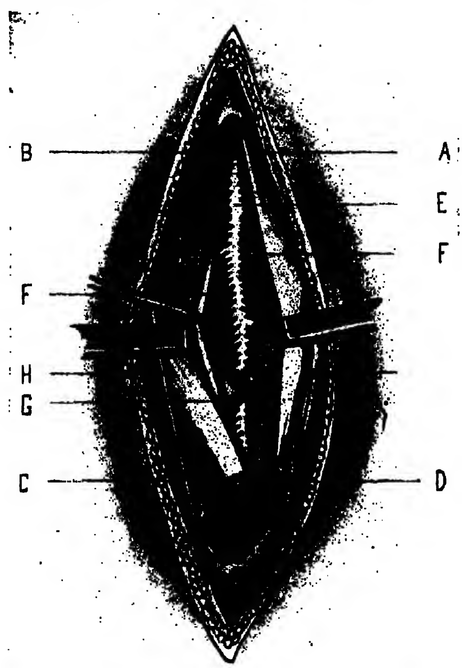

FIG. 286.—LIGATION OF LOWER THIRD OF RIGHT ANTERIOR TIBIAL.

A, Tendon of tibialis anticus, retracted inward; B, extensor proprius hallucis, retracted outward; C, extensor longus digitorum; D, annular ligament; E, anterior tibial artery and branches; F, F, anterior tibial venæ comites; G, anterior tibial nerve; H, inner branch of musculocutaneous nerve; I, branch of internal saphenous vein.

anterior annular ligament in the line of the wound (Fig. 286). Demonstrate the interval between the tendon of the tibialis anticus and the tendon of the extensor proprius pollicis, flexing the foot and retracting these tendons to their own side. The anterior tibial artery will be found between them, lying upon the anterior aspect of the tibia and held down by fatty areolar tissue, accompanied by two venæ comites and with the anterior tibial nerve on the outer side. Pass the needle from the nerve. In closing the wound, suture the anterior annular ligament. Note, if the artery were ligated after passing beneath the obliquely crossing extensor proprius pollicis, it would then have the tendon of the extensor proprius pollicis to its inner side and

the innermost tendon of the extensor longus digitorum to its outer side.

Ligation of the Posterior Tibial Artery.—The indications for ligation are wounds and aneurisms.

The sites for ligation are the upper third, not frequent, difficult because of its depth; the middle third, the same; the lower third, the most usual site; and behind the ankle, also a common site (Fig. 280, H, I, J, K).

Ligation of the Posterior Tibial in Its Middle Third.—The patient lies in the supine position, with the knee flexed and the leg

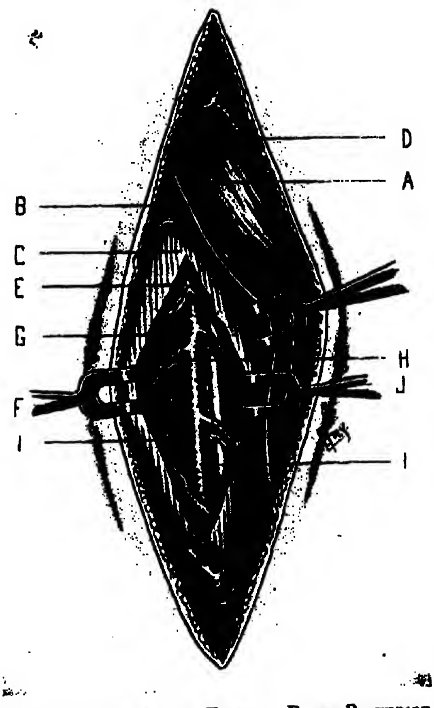

FIG. 287.—LIGATION OF MIDDLE THIRD OF RIGHT POSTERIOR TIBIAL.

A, Internal saphenous vein; B, internal saphenous nerve; C, soleus, incised vertically, and margins of incision well retracted; D, inner head of gastrocnemius strongly retracted outward; E, transverse intermuscular fascia; F, flexor longus digitorum; G, tibialis posticus; H, posterior tibial artery; I, I, posterior tibial venæ comites; J, posterior tibial nerve.

on the outer side. The surgeon stands to the outer side, cutting downward on the right and upward on the left.

The landmark is the inner margin of the tibia.

The incision is made about 7.5 cm. to 10 cm. (3 to 4 in.) in length, placed parallel with and 2 cm. (¾ in.) behind the inner margin of the tibia, along its middle third (Fig. 280, I).

Incise the skin and superficial fascia. Avoid the internal saphenous vein and the internal saphenous nerve (Fig. 287). Divide the deep fascia. The inner edge of the gastrocnemius should be identified here

and retracted outward. Having gone through the deep fascia the soleus is exposed, and is to be divided along its attachment to the tibia and its outer part retracted. The transverse intermuscular fascia (between the superficial and deep muscles of the back of the leg) is now in view, and is incised in the axis of the limb, whereby the flexor longus digitorum is reached, and by following along the surface of this muscle until nearly opposite the outer border of the tibia the vena comes interna, posterior tibial artery, vena comes externa, and posterior tibial are met in order, lying upon the tibialis posticus, or between it and the flexor longus digitorum (Fig. 288). Pass the needle

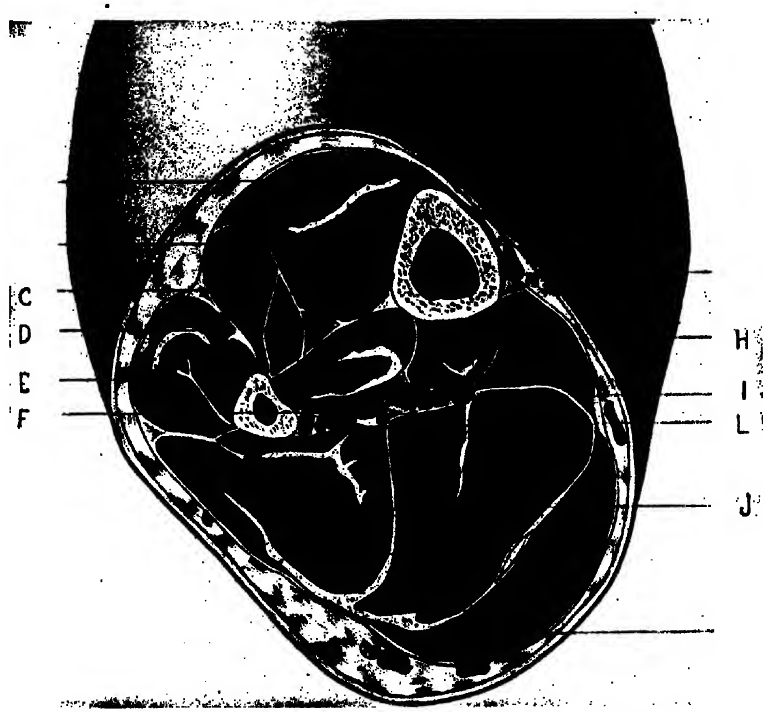

FIG. 288.—CROSS-SECTION OF THE MIDDLE OF THE RIGHT LEG.
A, Tibialis anticus; B, extensor longus digitorum; C, extensor pollicis; D, anterior tibial artery, vein, and nerve; E, peronei; F, tibialis posticus; G, long saphenous vein and nerve; H, flexor longus digitorum; I, posterior tibial artery, veins, and nerve; J, soleus; K, gastrocnemius; L, peroneal artery and veins. (Cross-section modified from Braune.)

from the nerve, including the venæ comites, flexing the knee and foot to relax the structures. An important part of the technic is that the knife should be held at a right angle to the surface of the muscle in cutting through the soleus, pointing toward the tibia until the transverse fascia is reached, and thereby wandering too deeply or in the wrong direction is less likely. If one incise too near the tibia the flexor longus digitorum will be divided and the interosseous membrane reached. While incising the soleus, do not mistake its central membranous tendon for the transverse intermuscular fascia. The artery lies about 3 cm. (1¼ in.) external to the inner border of the tibia.

Ligation of the Posterior Tibial Behind the Internal Malleolus. —The position is the same as for the ligation of the middle third.

The landmark is the internal malleolus.

An incision is made about 5 cm. (2 in.) in length, placed about 1.3 cm. (½ in.) posterior to and parallel with the inner malleolus (Fig. 280, K).

Incise the skin and superficial fascia, during which branches of the internal saphenous vein are encountered (Fig. 289). Expose the internal annular ligament and divide it over the vessels, the artery being found in the interval between the flexor longus digitorum and the flexor longus hallucis, surrounded by its venæ comites and with

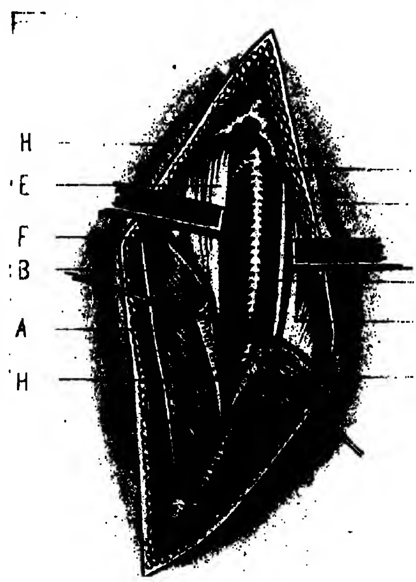

FIG. 289.—LIGATION OF RIGHT POSTERIOR TIBIAL BEHIND INTERNAL MALLEOLUS.
A, Branch of internal saphenous vein; B, branch of internal saphenous nerve; C, internal annular ligament (incised); D, tendon of flexor longus hallucis; E, tendon of flexor longus digitorum; F, tendon of tibialis posticus; G, posterior tibial artery; H, H, posterior tibial venæ comites; I, posterior tibial nerve.

the nerve upon the fibular side. The point of the knife should be kept toward the tibia in making the incision. Avoid opening the sheaths of the tendons. Behind the internal malleolus and the posterior surface of the tibia are four compartments, which, passing from the tip of the malleolus toward the heel, are—first, a canal in the annular ligament for the posterior tibial muscle tendon, a second canal for the flexor longus digitorum tendon, a third space occupied by the posterior tibial artery, its venæ comites, and the posterior tibial nerve, and a fourth canal for the flexor longus hallucis (Fig. 290).

Ligation of the Peroneal Artery.—The indications for ligation are rare, except for wounds, when the vessel is cut down upon at the point wounded.

Where the vessel is deliberately exposed for ligation the site usually selected is its middle, the upper part being but rarely exposed, owing to its depth.

The line of the artery extends from the middle of the popliteal space, on the level of the lower border of the tubercle of the tibia, arching slightly outward and then downward along the inner border of the posterior surface of the fibula. For the purposes of ligation the artery is represented by a line from the posterior border of the head of the

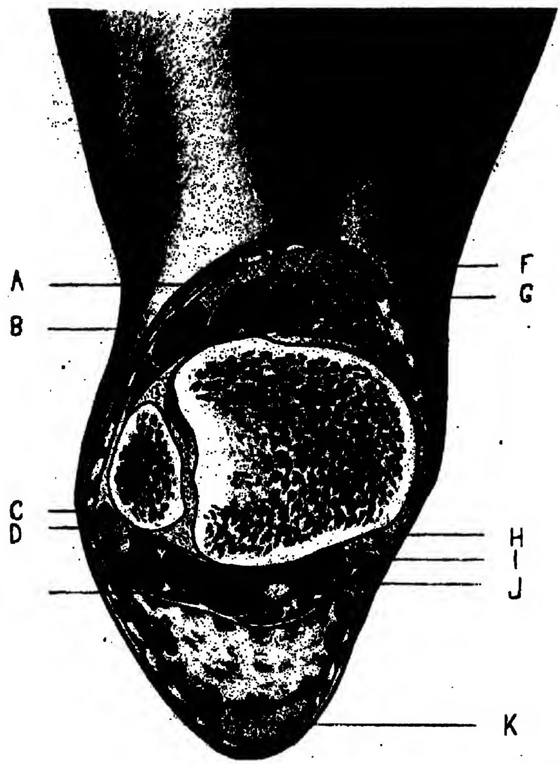

FIG. 290.—CROSS-SECTION OF THE RIGHT LEG JUST ABOVE THE ANKLE.

A, Extensor proprius pollicis; B, anterior tibial vessels and nerve; C, peroneus brevis; D, peroneus longus; E, flexor longus pollicis; F, tibialis anticus; G, extensor proprius pollicis; H, tibialis posticus; I, flexor longus digitorum; J, posterior tibial artery, veins, and nerve; K, tendo Achillis. (Cross-section modified from Braune.)

fibula to a point midway between the external malleolus and the outer margin of the tendo Achillis.

Ligation of the Peroneal Artery in the Middle of the Leg.—The patient lies on the shoulder and chest of the opposite side, with the knee flexed and the leg on the antero-internal surface. The surgeon stands on the outer side, cutting from below on the right and from above on the left.

The landmark is the external border of the fibula.

An incision about 7.5 cm. (3 in.) in length is made, parallel with and just behind the external border of the fibula, with its center over

the middle of the leg, which falls behind the peronei muscles (Fig. 280, L).

Incise the skin and superficial fascia. Branches of the external saphenous nerve and external saphenous vein are apt to be encountered here (Fig. 291). Expose the soleus (which at this site no longer arises from the fibula) and retract it upward and inward (incising its lower

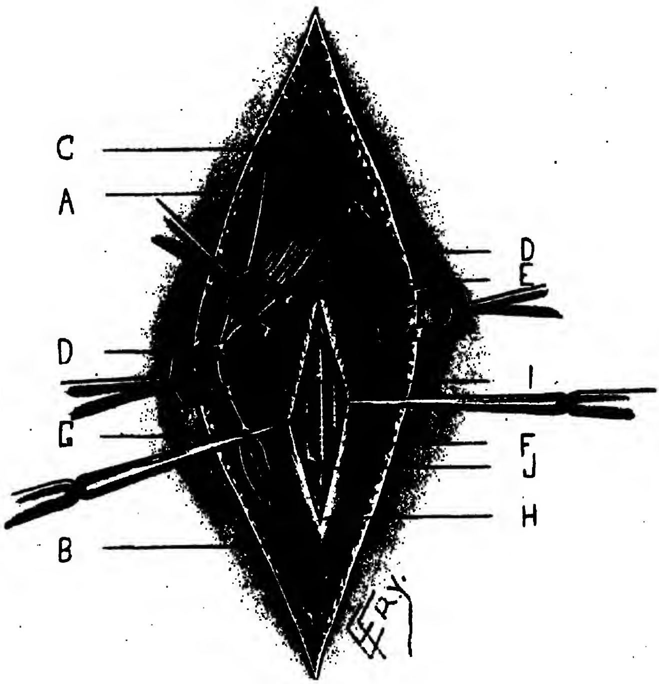

FIG. 291.—LIGATION OF RIGHT PERONEAL IN MIDDLE OF LEG.
A, Branch of external saphenous nerve; B, branch of external saphenous vein; C, gastrocnemius, retracted inward; D, D, soleus, retracted upward and inward; E, peroneus longus; F, peroneus brevis; G, tibialis posticus; H, flexor longus hallucis, incised, showing roof of aponeurotic canal inclosing vessels; I, peroneal artery; J, peroneal venæ comites.

fibers if any be found attached to the fibula at this height). Divide the deep fascia behind the peronei. Expose the flexor longus hallucis and incise through its thickness, close to the fibula, until the fibrous canal of which it forms the roof is reached. Divide the aponeurotic canal and expose the artery lying near the fibula, with its venæ comites, passing the ligature from the most convenient aspect (Fig. 288).

CHAPTER LXXIV.

OPERATIONS ON BONES AND JOINTS.

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GENERAL OBSERVATIONS.

In operating upon bone the surgeon should keep in mind that osseous tissue is made up of two-thirds earthy matter, which surgically is comparable to a foreign body. So long as there is no infection, this large amount of inorganic matter lies in normal relation with the organic cells, but when infection of bone with irritating bacteria takes place, the earthy material becomes most objectionable foreign matter, acting as an harbor for infecting organisms, into which the phagocytes cannot penetrate, and provoking irritation by its mechanical presence. The tendency of the inflammation is to continue until the necrotic bone has become broken down and absorbed or exfoliated in mass or in solution. Because of the meager resisting power against infection possessed by bone, and because of the prolonged destructive process which is started by infection, care to guard against such infection is imperative.

In the long bones the vitality of the bone depends upon its relation to the periosteum and marrow. These two structures should be respected. In young persons the periosteum will regenerate new bone, and this property often may be used to the great advantage of the patient.

The involucrum, or deposit of new bone which springs up from the periosteum about the necrotic sequestrum, is at first poor in earthy material and, therefore, very pliable and easily broken.

The operation of elevating the periosteum, with the view of saving it, is worthy of special consideration. It is important that the operation be begun right. This requires that the periosteum should be cleanly and strongly incised; a sharp-edged elevator (not a blunt instrument) should be used; the elevator should be kept close to the bone, working its way under the periosteum, which should be elevated untorn, carrying with it some of the bone, if necessary. It should not be scraped off and torn into shreds. At points where it is particularly desirable to preserve the periosteum or the muscular attachment into the periosteum, a thin shell of bone may be chiseled off. In the excision or curetting out of carious bones the interior of the bone may often be

wholly removed and the periosteal shell left. This should be done whenever practicable.

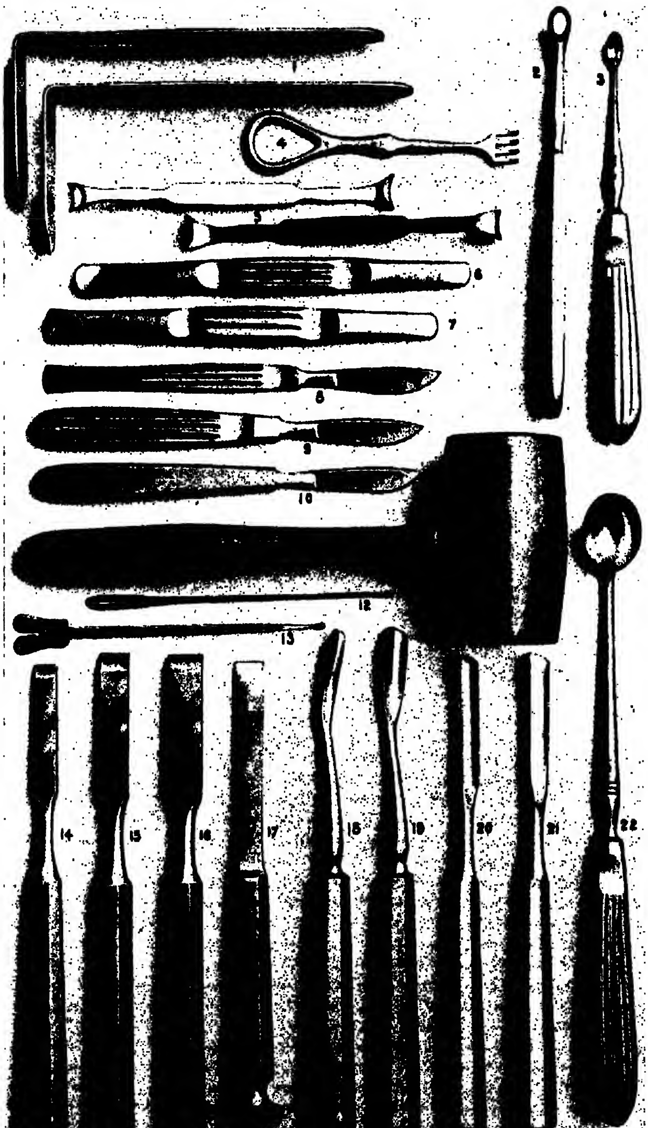


FIG. 292.—INSTRUMENTS EMPLOYED IN OPERATIONS ON BONES AND JOINTS.

1, Flat retractors; 2, 3, and 22, curettes; 4, hook retractors; 5, round retractors; 6, periosteal elevator; 7, periosteotome; 8, 9, and 10, knives; 11, mallet; 12 and 13, probes; 14, 15, and 16, chisels; 17, osteotome; 18, 19, 20, and 21, gouges.

In operating for acute inflammation in bone a point of tenderness can often be discovered before the patient is anesthetized, and this will represent the location of the disease. A sand-bag should be inter-

posed between the soft parts and the table when bone is chiseled, to take up the jar of the mallet and prevent traumatism to the opposite side

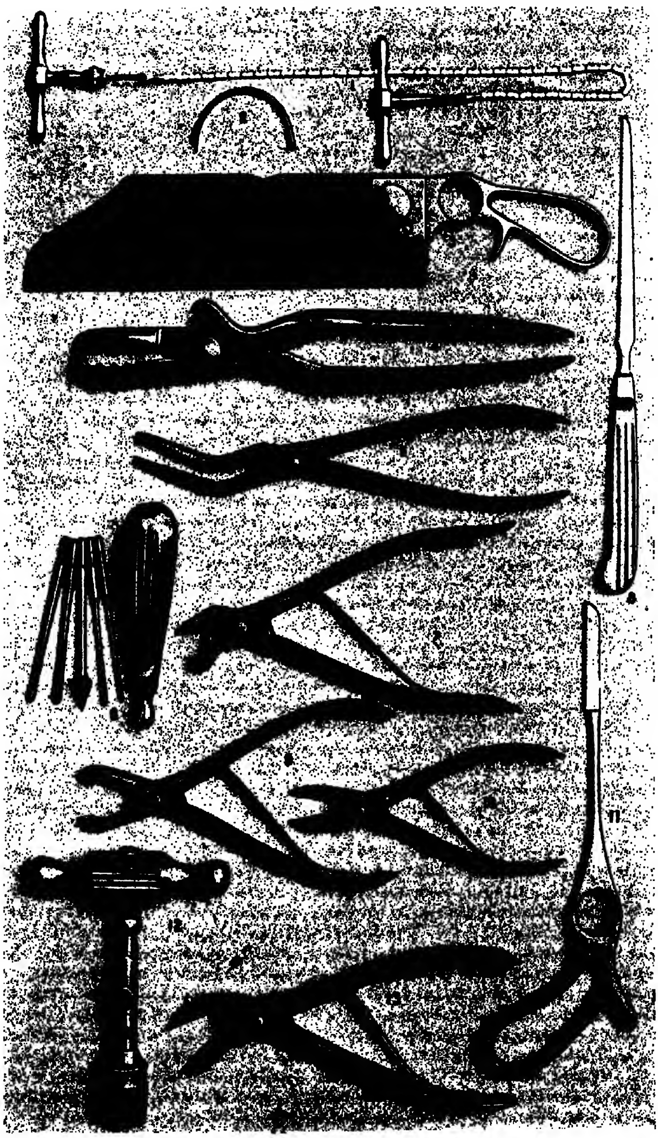


FIG. 293.—INSTRUMENTS EMPLOYED IN OPERATIONS ON BONES AND JOINTS.

10, straight bone-cutting forceps; 11, Adams saw; 12, trephine; 13, angular bone-cutting forceps. Not shown: Scissors, hemostats, needles, wire, suture materials, anatomic forceps, toothed forceps, mouth-gag, tracheotomy tube, bone-nails, Gigli saw, sponge-holders, and dental forceps.

of the limb. The surgeon should have well in mind the anatomy of the structures lying in relation to the bone, and also the location of epiphyseal lines in the young.

While typical operations are described, the performance of such operations is not to be aimed at. The surgeon should treat each case according to its peculiarities. Modern therapeutic measures are greatly reducing the necessity of mutilating operations upon joints and bones. When sinuses exist, which it is desirable to follow up to their origin, methylene-blue solution injected into the lumen produces a deep blue stain of the sinus wall, which enables the surgeon to follow it during the progress of the operation; a bismuth-vaselin paste also will show the sinus in a skiagraph. After operations on bones of the extremities it is well to elevate the part in order to minimize congestion and pain. Suture of bone is accomplished by means of chromicized catgut, silver wire, nails, rings, and the ordinary suture materials. The instruments employed upon operations on bones are shown in Figs. 292 and 293.

OPERATIONS FOR PERIOSTEITIS, OSTEITIS, AND OSTEOMYELITIS.

Periosteitis.—Periosteitis, with elevation of the periosteum by infective products, requires incision, which should be made parallel with the long axis of the bone. This incision should be made usually over the point of greatest tenderness, and should supply free and perfect drainage.

Osteomyelitis.—**Operation in the acute stage of osteomyelitis,** during the first forty-eight hours, is the operation of choice and should be practised whenever possible. If operation can be done at this early stage, the extensive destruction of bone which so commonly results from this disease can be averted. The limb should be emptied of blood by elevation, and the Esmarch bandage applied, jumping over the diseased part without compressing it, and the hemostatic constriction made well above the seat of disease. If periosteitis has developed, the bone should be exposed at that point. The periosteum should be incised to the full extent of its inflammation. It should carefully be stripped up from the bone, held apart by retractors, and the bone examined for openings through which pus is escaping from the marrow cavity. If an opening is found, the trephine or chisel should be applied at this place and the medullary cavity opened. If no fistulous opening is discovered, the medullary cavity should be opened at the most convenient point in the wound. When this operation is done early enough the medulla will be found inflamed and infiltrated with pus, but not destroyed. This inflamed medulla should not be curetted or disturbed. The simple opening for drainage of the bone canal should suffice to check the progress of the disease, and the earlier this operation is performed the less will be the subsequent destruction of bone. Upon opening the canal, however, if broken down and disintegrated medulla is discovered, or if the medulla is found to be displaced by pus, the bone covering this area should be removed up to the point where simply inflamed, but not disintegrated, medulla is found. The old practice of curetting out inflamed medulla cannot be condemned too strongly. The disease is a cellulitis, and the object of operation should

be to save as much tissue as possible. Free drainage, just as in cellulitis in other tissues; and not the removal of the inflamed structures, is the important thing. This medullary tissue plays too important a rôle in the economy of the bone to be sacrificed. Its friability and the ease with which it can be removed are no criteria of its importance, any more than are the same qualities in cerebral tissue. It should always be borne in mind that the vitality of the bone depends upon the periosteum and the medulla, and that the bone does not perish until these become separated from it. All operations for osteomyelitis should aim to preserve these two tissues, and to do so we may sacrifice as much bone as is necessary. Inflammatory products, confined under the pressure of the unyielding bone, rapidly destroy the medulla; and under the periosteum, until evacuated, they rapidly strip it up from the bone. The cavity of the bone having been opened, a rubber drainage-tube or a very loose capillary drain is inserted through the soft tissues down to the bone, and the wound left open or, if large, partially closed by suture and covered with a copious, moist, absorbent dressing.

The ideal operation for this disease is done in two stages: the first for drainage of the medulla, as soon as the diagnosis is made; the second during the subacute stage, for the removal of necrotic bone.

Operation in the subacute stage of osteomyelitis, after spontaneous evacuation of the medullary pus, is performed to the best advantage usually about two months after the acute onset. This can be done in the case of bones having a parallel fellow to act as a splint. At this time new bone is well advanced in development from the periosteum, where it has become separated from the old bone; a sequestrum may be present; and, if the death of bone has been extensive, demarcation is well defined. Esmarch anemia should be produced. The soft parts and the periosteum should be divided down to the necrotic bone. It is well to make the incision near the sinus opening, or to follow the old line of incision if the operation is a secondary one. The periosteum, the inner surface of which will be found covered with new bone, should be elevated whole from as much of the shaft as is necrotic. It should be retracted with the soft tissues, and the naked bone exposed. Any sequestra which are present should be lifted out, and the dead bone which is still attached should be removed. It will be observed that the dead bone is pale in color, does not bleed when cut, and is separated from its periosteum. In the case of the long bones this is best removed with the chisel and mallet. The operation should be carried in each direction until healthy bone is reached. Living bone is recognized by the presence of minute bleeding points, representing the divided blood channels. The surgeon should not expect free hemorrhage from the bone, he should stop at the first evidences of vitality, bearing in mind that the Esmarch method minimizes the show of blood. If the whole diaphysis is necrotic and is removed, profuse hemorrhage often takes place from the interior of the involucral shell. This is best controlled by packing with iodoform gauze.

As an operation of preference in osteomyelitis of the tibia, Nicholas advises proceeding as follows: The healthy remaining bone above and below is beveled so as to end in a wedge, unless the epiphyseal line renders it impossible. The periosteal new bone casing, after the removal of the dead shaft, is disinfected with phenol, followed by alcohol. This tube of periosteum is then caused to collapse, and its cavity obliterated by holding the opposed surfaces together with a few interrupted sutures of chromic gut. The soft parts are then loosely closed with some provision for drainage (Fig. 294).

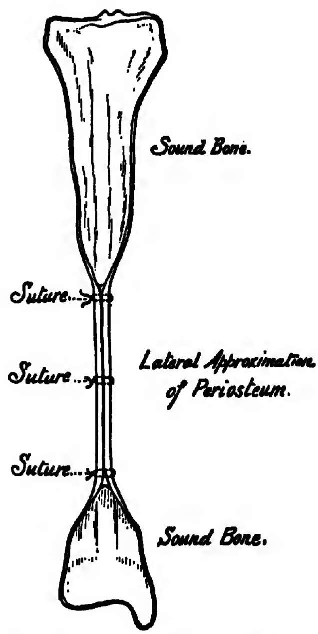


FIG. 294.—TREATMENT OF OSTEOMYELITIS IN THE SUBACUTE STAGE. (After Nicholas.)

Showing middle segment of bone removed, healthy bone ends made wedge shaped, and periosteum laterally approximated.

In the case of the femur and humerus this operation cannot be done to good advantage. In these bones it is well to leave the diaphysis until the new periosteal bone has become strong enough to support the limb. Often, however, a radical operation may be done and the fragile bone-shell preserved by applying the same splint apparatus as would be employed in the treatment of a fracture of the particular bone. The best results are secured in the case of either of these bones, if the whole diaphysis is necrotic, by freely exposing it and laying open the medullary canal or chiseling fenestra into it at frequent intervals. This gives drainage, and the sequestrum remains as a splint until the involucrum has become sufficiently strong.

Operation in the chronic stage of osteomyelitis is done when the necrotic shaft is broken down, the new periosteal bone is thick enough to support the limb, and often hard and eburnated, and when there may be present dense deposits of endosteal bone. It is in this stage that operation is usually performed, and to this the term "sequestrotomy" belongs. It was formerly the custom to expose the bone at the sinuses, enlarge the opening sufficiently to remove the sequestrum, scrape out the cavity, and pack it with iodoform gauze. In the case of very small bone cavities this method is still the best. In the ordinary large cavities, however, on account of the great slowness with which the new periosteal bone or involucrum grows into the defect from which the sequestrum was removed, and on account of the fact that by this method small sinuses leading to other sequestra are apt to be overlooked, giving rise to long-continued suppuration and often requiring subsequent operations, the old method has been supplanted by more radical measures. These measures for healing the defect

in the bone, resulting from the disease and from the operative removal of the dead bone, may be described under the following headings: (1) Autoplastic Operations with Soft Tissue; (2) Autoplastic Operations with Bone; (3) Bone-grafting and Transplantation; (4) Aseptic Bone-cavity Filling.

The ingenuity of surgeons has devised many methods of treatment, but only the most important will be described. Each case is peculiar, and practical familiarity with the principles of surgery is absolutely essential for success. These operations are all done to the best advantage with the limb rendered anemic by the method of Esmarch. It should be understood that there is no sharp dividing line between the subacute and chronic stage of the disease, and any of these procedures may be applied in the former, provided the limb is supported so that the involucrum is kept immovable during the healing process.

Autoplastic Operations with Soft Tissue.—The bone cavity should be completely unroofed; that is, the involucrum should be cut away with chisel and rongeur throughout the whole length of the cavity on the wound side of the bone, to such an extent that the remaining trough represents nowhere more than half a circle. This bone trough should be thoroughly scraped out with the curette. Sharp and rough edges of bone should be removed because of the tendency of projecting points to fall into decay. A search should be made for other sinuses, especially small ones. These should be laid open freely. It will often be found that such sinuses lead out to the opposite side of the bone and end under the soft tissues. Invariably a periosteitis has existed at such places and often a superficial sequestrum will be discovered. It is well at such points to lay open the soft tissues to the surface, and introduce a drainage-tube down to the bone, after having removed any dead bone which may be present. Very commonly, however, these places heal without making the additional opening through the soft tissues.

The cavity should now be sterilized by means of pure phenol applied for two minutes, followed by alcohol, and then a washing out with salt solution. There are other measures for rendering bone cavities aseptic which the choice of the surgeon or the circumstances of the case may prompt him to adopt. Filling the cavity with olive oil and raising the oil to a temperature of 212° F. by the thermocautery; conducting live steam by a rubber tube into the bone, the surrounding tissues being well protected by cold wet compresses; filling the cavity or swabbing it out with tincture of iodin, if it is not too large, and washing this out immediately with alcohol; irrigation with formaldehyd and other antiseptic solutions—all of these methods have proved efficient. It should always be borne in mind that treatment such as this, while it destroys bacteria, also leaves a layer of devitalized tissue lining the wound, and if it is desired that transposed living tissue shall grow adherent to the wound surface, it is best to defer the transposition until it can be made against aseptic granulations. Therefore, after such sterilizations, the best success is secured by packing the cavity with

gauze and awaiting the development of a layer of granulation tissue. By this means a layer of vascular soft tissue is secured, and an opportunity is afforded for the elimination of necrotic particles. If the cavity with the whole leg is kept dressed under scrupulous conditions with copious wet salt solution or borosalicylic dressings, clean granulations will be secured, which will require no further chemical treatment. After granulations have appeared, before proceeding with the plastic operation, the cavity should be washed out with salt solution; but the granulations should not be traumatized or made to bleed with either sponges or instruments. The surgeon may then proceed to cover these granulations by flaps of skin turned in from the neighboring surfaces, or by skin-grafts. If neighboring attached skin is simply turned down into the bone excavation, the operation may usually be completed successfully at the first stage; but if grafts or skin, swung about upon a pedicle, are employed, the presence of healthy granulations adds much to the insurance of success.

If the bone cavity is not deep and the surrounding skin is in good condition, the skin may be dissected up on either side for the length

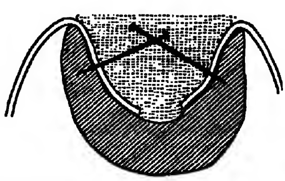


FIG. 295.—SKIN TURNED INTO BONE CAVITY, HELD BY NAILS AND GAUZE.

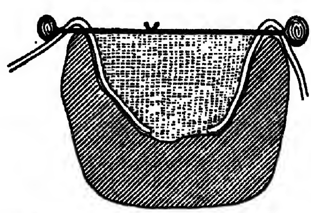


FIG. 296.—SKIN TURNED INTO BONE CAVITY, HELD WITH SUTURES AROUND BOLSTERS OF GAUZE. GAUZE PACKING.

of the wound and simply turned down into the bone trough. It may be held here by bone-nails and a light gauze packing (Fig. 295). Mattress sutures are also of service (Fig. 296). Pediculate flaps may be turned in and held in place in the same manner. In cases in which there is a large cavity it is wise not to attempt too much at one sitting. The plastic operations may be done to advantage at intervals. Flaps for this purpose may be taken from the other leg when no other skin is available.

Autoplastic Operations with Bone.—These operations are proceeded with as above, except that as little of the new bone as possible is removed, only enough for the removal of sequestra and the cleansing of the cavities. The best results are procured here also by operating in two stages, although immediate completion of the operation may successfully be done in one stage. One or both sides of the involucrum may be separated above, below, and longitudinally by the saw and chisel, and turned into the cavity. This is essentially the construction of a flap of soft parts and bone. By such an operation the sides of the involucrum may be made to collapse and obliterate the bone cavity (Fig. 297). It is the most satisfactory of all the osteoplastic methods.

Bier has described an operation whereby all of the involucrum is saved. By this method the cavity is uncovered by marking out a quadrilateral flap, corresponding in length with the length of the cavity. The soft tissues are incised, and in the same lines the bone is divided with chisel and saw. A skin-periosteum-bone flap is elevated as a valve, the cavity of the bone cleaned out and sterilized, and the flap sutured back in place (Figs. 298

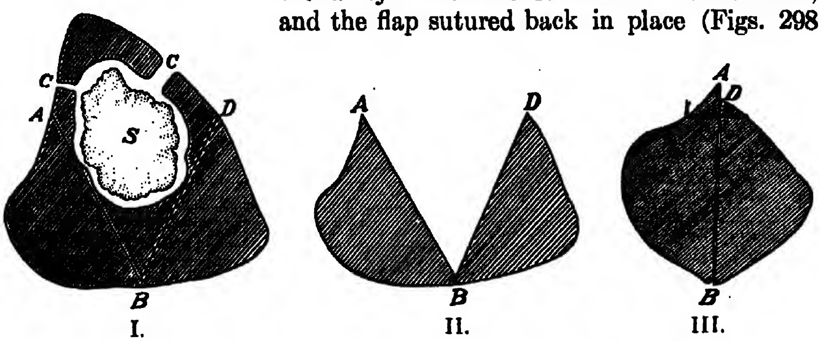


FIG. 297.—LONGITUDINAL FRACTURE METHOD OF OBLITERATING BONE CAVITY.
I. *S*, Sequestrum; *C*, cloaca; *AB*, *BD*, planes to be chiseled. II. Showing cleaned out involucrum. III. Involucrum fractured longitudinally, closed up, and wired.

and 299). The cavity fills with clot, which becomes organized and penetrated by osteoblasts. The success of this operation depends upon its asepticity; and the difficulty of rendering these wounds with sinuses clean at one sitting demands that the operation be done in two stages. If this modification is applied, it becomes the ideal procedure, although it is applicable to comparatively few cases.

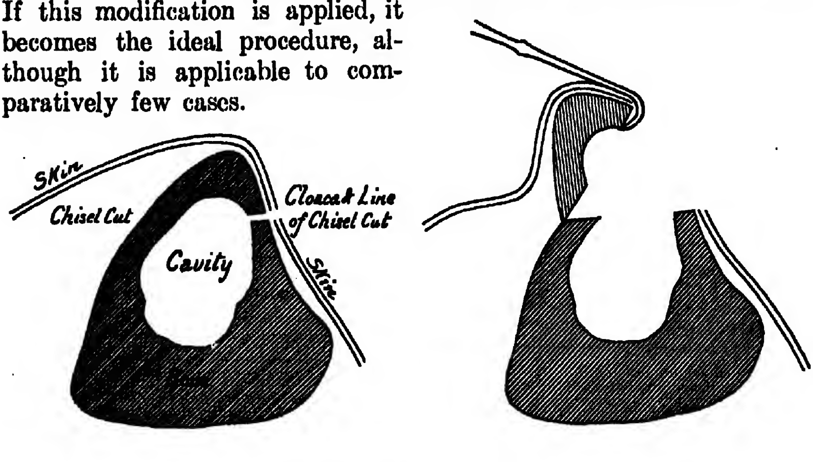


FIG. 298.—BIER'S BONE-FLAP METHOD OF TREATING BONE CAVITIES.
A, Lines of division. *B*, Flap held back with retractor and cavity exposed.

Bone-grafting and Transplantation.—By this operation living bone is transplanted, with its vital connections not divided, to fill the defect in another bone. The operation in which detached fragments of bone are employed cannot properly be described under this head. Bone may be transplanted from the patient or from another animal. The

general principles of surgery and the ingenuity of the surgeon are called upon to solve each problem separately. A few illustrative methods may be given.

T. W. Huntington[2] treated a defect 5 inches in length in the middle of the tibia by sawing the fibula in two in such a way that the upper end of the lower fragment of the fibula was fitted into a depression made in the lower end of the upper segment of the tibia; nine months later the fibula was again sawed through at its lower end, and in a similar manner fitted into the upper end of the lower segment of the tibia. Solid bony union was present in four months after the last operation, and a year later this transplanted middle segment of the fibula was discovered by the x-ray to have enlarged to the size of the other tibia, and a strong and serviceable leg was the result. In a similar case I have split off a longitudinal segment of the fibula and bent it into a defect in the tibia; and B. F. Curtis[3] reports having cut out a section of fibula, leaving it attached to the muscle and fascia, separating the intervening tissues, and placing it in a gap in the tibia.

FIG. 299.—BIER'S OSTEOPLASTIC RESECTION OF THE INVOLUCRUM. Flap turned back and cavity cleaned out.

In a case in which there was an extensive defect in the continuity of the tibia with ankylosis of the knee, N. Senn[4] turned down a pedicled flap containing the patella and fixed the latter to the upper end of the lower segment of the tibia. The defect was larger than the patella, and the operation was completed, after bony union had taken place, by bisecting the patella longitudinally and sliding up one of the halves into osseous contact with the upper segment of the tibia. Solid union was secured in all the bony appositions. Bardenheuer[5] transplanted the spine of the scapula into a defect of the upper end of the humerus.

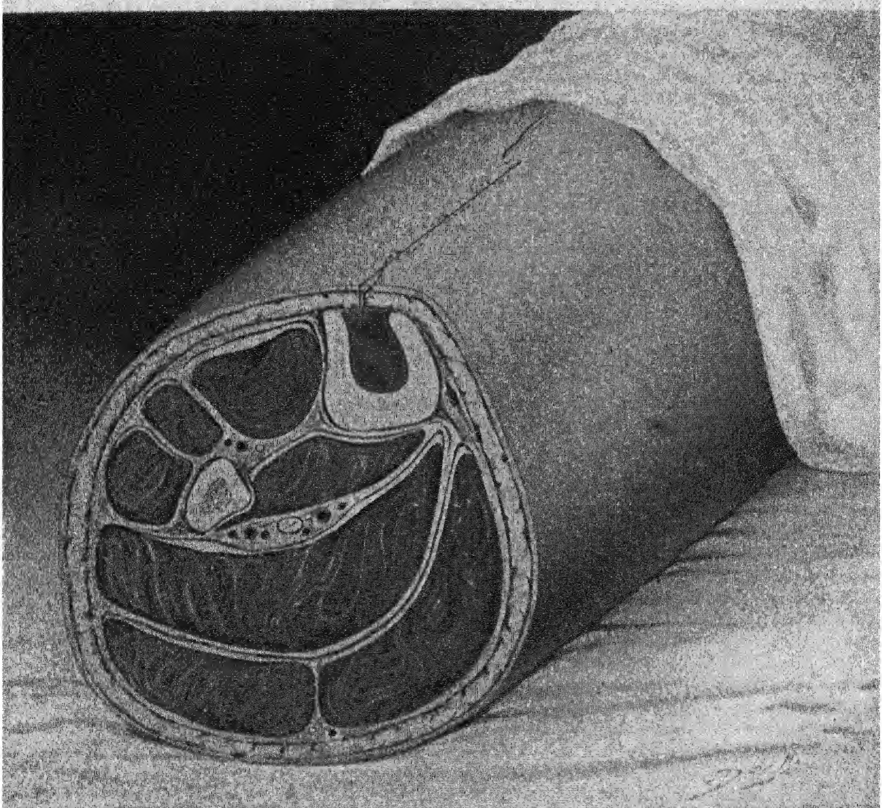
Phelps, Morton,[6] and others have filled the defect in the tibia by exposing a bone in a dog's leg, turning out a flap containing a sufficient length of bone to fill the gap, and suturing it in place, holding the dog's leg to that of the patient by plaster dressing, and severing the flap from the dog after union had taken place. The newer methods

of operation, which have proved so successful, render such a difficult procedure as this unnecessary.

Aseptic bone-cavity filling is applied to cavities which are the result of injury, aseptic operation, tuberculosis, and to osteomyelitic cavities which have previously been cleansed and become lined with clean granulations, and to cavities which can be sterilized by the methods described above under *autoplastic operations with soft tissue.* The operation is not applicable to acute infective or suppurative cases. Many methods for the filling of bone cavities with foreign material have been devised. Detached fresh bone should be classed among these materials, for in the light of modern knowledge its use cannot be spoken of as bone-grafting. When a piece of bone, whether fresh or old, is detached from its vital connections and implanted elsewhere into a bony defect, it becomes dead material and is amenable to the laws which govern the presence of foreign bodies under such circumstances. If the microörganisms of suppuration are present, it acts as a foreign body, and suppuration will continue until it is removed. If it is covered in under aseptic conditions and has about it osteogenetic tissue, the process of new connective-tissue growth goes on until it becomes firmly incorporated in the new tissue. Its proteid cells break down and are absorbed, and the earthy framework which remains serves as a scaffolding into which the new tissue continues to grow. As the interstices become invaded by the new tissue, which histologically is the same as callus, the osteoclasts take up the solid material of the foreign bone, and thus, as an organized structure, it disappears. In the new tissue which replaces it osteogenesis progresses until it is transformed into new bone. This process is essentially the same if some substance other than bone is used. The materials which best lend themselves to this operation are bone chips, blood-clot, sponge, and substances which are wholly or partially capable of being absorbed, thus furnishing a support to the newly growing bone-making tissue. The best substances for surgical use are those having interstices or those which are mechanical mixtures of ingredients of different degrees of absorbability. When a cavity is filled with these substances, if there is not enough skin or soft tissue to cover it, it may be covered with a layer of silver-foil or rubber tissue.

Schede Clot (Plate II.).—The first operation devised for this aseptic cavity filling was that of Schede. He covered the sterilized bone cavity and permitted it to fill with blood. This coagulates, and the clot becomes penetrated by the new tissue and absorbed, just as implanted bone does. Although it is still much used and is a valuable expedient, it has the disadvantage that absorption goes on more rapidly than bone building. The success of the Schede clot operation, like all of the expedients for cavity filling, depends upon the asepticity of the operation. The bone cavity must be sterilized and allowed to fill with blood. If it is lined with clean granulations, these may be incised or scraped to provoke bleeding. Often the operation is done immediately after removing dead bone, but with less promise of success than

PLATE II.



SCHEDE CLOT.

nsverse section of leg, showing cavity in tibia cleaned out, filled with coagu blood, and covered in by deep suture of the skin and subcuticular suture.

when performed as a secondary operation. Even the bacteria of the air threaten the success of this operation, and every precaution to exclude microörganisms must be employed, not only at the operation, but also at the first dressings.

The technic of *bone transference* from another animal is briefly as follows: Under scrupulous asepsis the previously sterilized bone cavity is exposed. It is best that a tourniquet be not employed, in order to obviate the danger of having the transferred bone separated by blood after the wound is closed. The bleeding should be checked before the introduction of the transferred bone. The most convenient animal is a young dog. The required length, *e. g.*, of the humerus, is removed by cutting forceps, the muscle is stripped from the bone, and it is immediately transferred to the waiting cavity, and the soft tissue is closed over it without drainage. It is not necessary that this piece of bone be thick, indeed, it is doubtful if as good results are secured with large as with smaller bones. An advantageous modification of this operation consists in splitting the fragment into several longitudinal pieces. This gives the connective tissue a better opportunity to penetrate. After the closure of the wound the limb should be put up in plaster-of-Paris or a splint to insure immobility of the parts.

Bone chips are prepared as follows: The tibia or femur of the cow is sawed into strips about $\frac{1}{8}$ inch in thickness. These strips are freed of periosteum and marrow and immersed in a 10 per cent. solution of hydrochloric acid in water. This solution is changed daily for ten days. The strips are then washed in sterile water, followed by alkaline solution, and stored in a solution of ether saturated with iodoform. Before using, the ether should be washed out with alcohol. These strips may be cut into the desired length and the cavity filled.

Senn's bone chips are made from the compact substance of the long bones of the cow, cut into cubical pieces about $\frac{1}{8}$ inch thick. These are decalcified in a 50 per cent. solution of hydrochloric acid for ten or fourteen days; they are then washed in weak alkaline solution, and preserved in absolute alcohol. When used, they are cut into small chips, sprinkled with sterilized iodoform powder, and packed into the cavity.

Other absorbable materials, such as catgut, cellulose fiber, sponge, and ivory; and *non-absorbable materials*, such as celluloid perforated hard rubber, metals, and plaster-of-Paris, have been used. Brabant[7] reports the successful employment of copper amalgam, which was pressed against the sides of a large cavity until the whole surface was covered.

No method of filling sterile bone cavities has met with greater success than *the method of Mosetig-Moorhof*,[8] of Vienna, which was reported in January, 1903. The material used consists of 60 parts of iodoform, 40 parts of spermaceti, and 40 parts of oil of sesame. These ingredients are mixed and slowly heated to 100° C., and, when allowed to cool, form a soft solid which remains solid at the temperature of the body. When using it, it is heated to 50° C., being constantly stirred to

keep the iodoform evenly distributed, and poured into the bone cavity, where it immediately solidifies. Its constituents are such that it is slowly absorbed after the manner of implanted bone, being permeated by new connective tissue which undergoes ossification. Mosetig-Moorhof in his technic employs the Esmarch bandage to render the limb anemic. He cuts away sinuses and diseased skin. He insists that the cavity be lined with healthy bone, that the soft parts be thoroughly freshened, and that the cavity be both sterile and dry. He cleans it out with the chisel and scoop, washes with salt solution, and sponges the walls with a 2-per cent. formalin solution. This is followed by a hot-air blast for the purpose of drying. The filling is poured in from a bottle, the periosteum is closed with catgut, and the integument with fine silk. Elsberg[9] overcomes the tendency of the filling to remain fluid and to become extruded from the cavity, by cooling it down to the consistency of putty, and then putting it into the cavity. This also helps to control oozing. It is best to remove the Esmarch constriction before introducing the filling, in order that all bleeding may be stopped. If oozing persist, it may be controlled by pressure, moist heat or the cautery.

The filling of defects due to—(1) localized caries, (2) tuberculosis, (3) injury, and (4) operative excisions may be accomplished by any of the above described methods. Autoplastic operations with soft tissue have the disadvantage of leaving unsightly scars and distortions and tend the least toward strengthening the bone. The operations which aim to reproduce bone are the most useful.

In *isolated chronic abscess* of bone and in epiphyseal *caries* and *necrosis*, after laying open the cavity and scraping out the softened and diseased tissue, the cavity may be sterilized by 95 per cent. phenol, followed in a few minutes by alcohol, and this by saline solution, and bone filling introduced according to the rules laid down above. In epiphyseal disease there is often effusion into the joint, which may require aspiration or incision at the time of operation.

Tuberculosis of bone, if not complicated by mixed infection, is most successfully treated by the immediate introduction of bone filling after the operative removal of the tuberculous bone. The filling of Mosetig-Moorhof, after removal of carpal and tarsal bones for tuberculosis, in many cases obviates the necessity of amputation.

After accidental *compound fractures* with loss of bone, autoplastic operation with bone is indicated, but unless the possibility of infection has been overcome, bone filling should not be attempted. Later, if there is a defect, when aseptic conditions can be secured, any of the bone reproducing operations may be done.

After operative excision of bone for *tumors* or other non-infective diseases the ideal conditions for bone plastic are present, and the surgeon may employ any of the above-described operations with the best hope of success.

RESECTION OF BONE FOR MALIGNANT TUMORS.

Excision of only the diseased portion of the bone has long been practised in cases of benign tumors, but in the case of malignant growths the operation has been confined to the flat bones. Until the last decade, most surgeons treated malignant diseases of the long bones of the extremities by amputation. Koenig,[10] in 1894, called attention to certain giant-cell sarcomata of the medulla of long bones, which were so benign that he had cured them with the curette. Then came Mikulicz[11] in 1895 and Weisinger[12] in 1898 with reports of cases of resection which showed results better than amputation, because less mutilation was done. Morton[13] in 1898 reported two cases of excision of the upper end of the tibia for sarcoma. The shortening was about 8 cm. In the same year Karewski[14] and Frank Hinds[15] reported similar cases. The latter case was a giant-cell sarcoma of the lower end of the femur involving both condyles. The cavity was chiseled and scooped out, and the interior treated with chlorid of zinc. The cavity filled with new bone, and at the end of two and a half years there was no recurrence.

In many cases of malignant disease we now consider excision of the diseased portion of the bone to be the best surgery. This is especially indicated when early diagnosis is made; and the use of the x-ray has contributed much to this end. Moreover, patients come more willingly to operation if they know that the limb is not to be sacrificed, and earlier operation is thus rendered possible. It is difficult to persuade patients with a scarcely discernible and painless swelling to consent to amputation. The operation almost invariably is deferred. But they will consent to excision, and for this reason its results are better. An early excision is of more value than a late amputation, for it should remove all of the local disease as completely as amputation does. If metastases have taken place, amputation offers nothing better than excision. If metastases have not taken place, the sooner the tumor is removed the better; and it is necessary to remove only the tumor. In doing this, if much bone has to be sacrificed, the surgeon then is confronted not with a condition that threatens the patient's life, but only the usefulness of the limb. To restore this he has all of the resources of plastic surgery; and, if he fail, the worst that can come is the removal of a useless member.

The operation of excision of the long bones for malignant disease has been advanced to such a point by Koenig, Mikulicz, Weisinger, Cramer, Jenkel, Goldmann, and others, that it is now a well-accepted procedure. Mikulicz has gone so far as to advocate resection in all cases of sarcoma of bone where the disease can be excised without injury to the vessels or without removal of so much tissue that the limb is rendered useless (Fig. 300).

The earlier operators laid stress on the kind of tumor that the surgeon had to deal with. I believe that this need be given but little consideration. In all cases the aim is to remove all the growth, irrespec-

tive of the degree of malignancy, and with as little damage to the parts as possible. Certain tumors, such as giant-cell sarcoma, occurring in the upper end of the tibia, the femur and the humerus can be removed by thoroughly curetting and chiseling out the bone cavity in which it is growing. This tumor is similar to epulis of the alveolar process which is best removed by a limited excision of the bone, performed with the rongeur or saw. E. E. Goldmann[16] reports 2 cases of periosteal sarcoma of the tibia cured by resection. One was situated in the upper and middle thirds of the bone. Thirty centimeters of the shaft were excised. He then divided the fibula below its head and placed the upper end of the peripheral fragment in a hole bored in the upper fragment of the tibia. Ten weeks after the operation the union was so solid that the leg would support the patient's weight. Two years after operation the fibula had become as large as the tibia of the other leg. In another case the tumor involved the lower two-thirds of the tibia, which were excised. The fibula was divided in two places, the freed segment fitted into the tibial gap, and sutured. Complete union was present in five weeks.

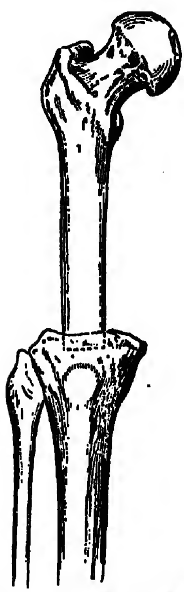


FIG. 300.—MIKULICZ'S RESECTION OF LOWER END OF FEMUR.

Accumulated evidence shows that in some sarcomata the disease can be cured by chiseling, preserving the continuity of the bone; in other cases a resection of the entire thickness of the bone suffices; in others an amputation a short distance above the disease is necessary; and in extensive malignant growths involving the soft tissues as well as the bone, exarticulation at the joint above the disease is imperative. The results after resection and amputation are equally good if the tumor is confined to the bone, and almost equally bad if there is infiltration of the muscle.

The operation of resection in preference to amputation is a great advance in operative surgery, and is not only destined to preserve limbs, but to lower the mortality of malignant disease. It is limitless in its field of application; it is applicable to all the bones of the extremities. It is not only possible to resect segments of long bones, but the whole bone may be removed and the patient left in a more useful state than he could be after amputation. This is illustrated by the removal of the humerus and the articulation of the ulna to the shoulder, leaving a woman who earned her livelihood by needlework a functionating hand.

ARTHRECTOMY, ERASION, OR SYNOVECTOMY.

This operation consists in the removal of the synovial membrane lining the joint. The operation may include the removal of the diseased ligaments and other soft structures, and the scraping or tearing away

of superficial disease of the cartilages or bones; but if section of the bone has to be done the operation constitutes an excision. Arthrectomy was first practised and described by G. A. Wright.[17] The operation is indicated in disease which begins in the synovial membrane, and before advanced involvement of bone has taken place. It is indicated in most of the diseases which would demand excision if allowed to go on. It is preferable to excision in growing children. It is indicated in chronic and suppurative synovitides, in tuberculous synovitis which resists milder measures, and in the fungous articuli of the old authors in which the capsule and the parasynovial tissue form a gelatinous mass ½ to ¾ inch thick. Its advantages are that it does not interfere with the growth of the epiphysis, the ligaments about the joint are less damaged, shortening of the limb is not produced, and the dangers of the operation are less than excision. If, however, the operation fail to remove all the disease, and recurrence takes place, excision is rendered more difficult. The operation will be described in connection with the knee-joint, to which it is chiefly applicable.

OSTEOPLASTIC OPERATIONS.

Osteoplastic operations for the defects of long bones following disease and injury have been described under operations for osteomyelitis, and the most important operations of that kind are to be found under that heading. There are, however, certain other methods of bone plastic which deserve attention.

In the skull, after trephining, the button of bone may be replaced and the permanent closure of the skull expected. The zygoma is turned down in the flap of soft tissues in exposure of the temporo-zygomatic fossa, and sutured back in place. Osteoplastic resection of the skull is described under Surgery of the Head, Vol. III., p. 261. This operation is a type of temporary resection, in which the bone is left attached to the overlying soft parts with the view of replacing it. The operation is practised on the spinal column to expose the cord, the flap containing the laminæ and spinous processes; it is practised upon the ribs, upon the lower jaw, in amputations to finish the bone ends, in rhinoplasty, and upon the bony prominences about the joints in operations for resection. The aim of the operation is that the vitality of the bone shall not be destroyed, and that the bone shall be replaced as living tissue.

Osteoplastic Operations for Cranial Defects.—In order to fill the defects resulting from loss of portions of the cranium any of the operations described under *Bone-grafting* and *Bone-filling* are indicated. There are also certain special operations for this purpose.

If the opening is small it may be exposed by a straight or curved incision through the scalp, the connective tissue removed from the dura, and from the opening, and the edges of the bone freshened. The trephine may then be applied to the healthy skull in the neighborhood, and the outer table cut through. The button thus marked out is lifted

up and placed in the cranial defect with its periosteum against the dura, and the wound closed.

Larger defects may be filled by marking out a flap in the scalp of the desired shape and then sawing or chiseling through the outer table of the skull, and lifting this up with the flap of scalp and swinging it into place. B. L. Eastman[18] describes a case of large defect of the parietal bone, in which he cut out a plate from the outer table of the opposite parietal bone, removed it from all of its connections, and fitted it into the defect, with successful results. Carl Beck[19] has successfully employed a flap of temporal fascia and periosteum to cover cranial defects. The defect is exposed by a curved incision, and the scalp dissected from the temporal fascia. The scar tissue is removed from the defect and the opening slightly enlarged above to expose an edge of dura mater. A flap of temporal fascia, muscle, and periosteum is turned up from below, and the fascia is sutured to the edge of the dura, leaving the periosteum of the flap outermost. The scalp is then sutured over all. Beck reports securing in this way not only a good substitute for dura, but also the development of bone from the reflected periosteum.

W. W. Keen[20] has described a valuable method of filling in skull defects. He turns back a scalp flap and freshens with the rongeur the margin of the opening. Then with a gouge and mallet a number of pieces from the outer table of the adjacent skull are chiseled off and distributed evenly over the defect. The flap of scalp is sewed in place over the bone chips. He has employed this method, always with success, in over 20 cases, the chips never undergoing necrosis, and eventually becoming incorporated into a solid bony plate. Areas as large as 6 to 7 cm. by 3 to 5 cm. have thus been treated.

OSTEOTOMY OF THE LONG BONES.

Osteotomy consists in the cutting of bone, but the term is applied usually to the operative division of a long bone for the purpose of correcting deformity. Such deformity is usually due to badly united fractures, the distortion of rickets, or certain ankyloses following inflammation. The operation was originally performed through a free opening, but since the time of von Langenbeck it has been done through a minute skin opening just large enough to admit the chisel after the manner of tenotomy. The skin incision should be made in the direction of the long axis of the limb. The bone is divided by means of the narrow chisel, called osteotome, and a mallet. The osteotome was perfected by Macewen, and differs from the chisel, which has only one side beveled, in that both sides are evenly ground. The cutting edge is from $\frac{3}{8}$ to $\frac{3}{4}$ inch in width. Osteotomes of different thickness may be used, the thinner being used last as the wound becomes deeper. These osteotomes are marked with the measuring grooves on the blade to determine the depth of the wound. The best mallets are those made of wood or rawhide.

The extremity is best placed on a firm sand-bag to take up

the impact of the mallet. The osteotome is introduced into the wound, passed down to the bone, and then rotated to the desired position. It should be held firmly in the closed hand with the inner side of the wrist resting on the skin, so that it is under control. It is driven a short distance into the bone and then rocked until it is loosened, and applied a little further along in the same line. It is well to keep the osteotome in contact with the bone, lest the location of the cut be lost. Gradually, in this way, it is worked along until the bone is divided. The osteotome should never become tightly wedged, but should always be kept loose by a rocking motion, both vertically and laterally, after each stroke of the mallet. The surgeon should have in his mind the important structures lying near the bone, and care should be exercised lest the chisel be driven into the tissues on the opposite side. The accepted practice is to carry the osteotomy nearly through the bone and then to complete the operation by forcibly fracturing. Often in children it is not necessary to make a complete fracture. The deformity is corrected, the small wound dressed without suture, and the bone treated as a fracture. The fine saw of Adams is sometimes used instead of an osteotome. In cases in which osteotomy is done for the purpose of producing a false joint, passive motion must be continued every day from the time of operation, even though an anesthetic is required.

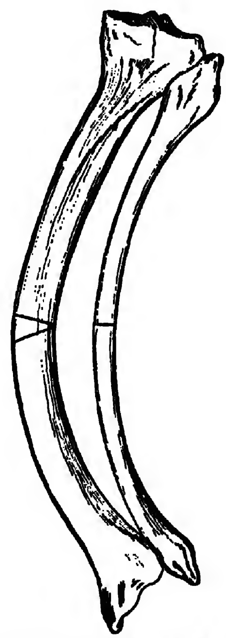


FIG. 301.—CUNEIFORM OSTEOTOMY.

Cuneiform osteotomy (Fig. 301) consists in the cutting out of a wedge-shaped piece of bone to correct deformity too great for simple linear osteotomy. This is a complicated operation and requires an incision large enough to permit the removal of the wedge of bone. Cuneiform osteotomy is applied in extreme deformity of the tibia or femur resulting from rickets. It is rarely required in old ankylosis of the knee with flexion. In the latter case a wedge composed of the lower end of the femur and the upper end of the tibia is removed. The operation of cuneiform osteotomy is done advantageously by cutting out a notch in the bone with the bone chisel and then chiseling this larger and deeper until the desired cuneiform division of the bone is reached.

Osteotomy of the Femur.—For Ankylosis of the Hip-joint.—This operation is indicated in cases in which there is ankylosis with bad position of the thigh. The object is not to secure mobility, because this is rarely, if ever, accomplished, but to put the thigh in better position for walking.

Osteotomy of the Upper End of the Femur.—This operation is done with the saw or with the osteotome.

Adams' operation (Fig. 302, *A*) is as follows: The left thumb compresses the soft tissues against the bone, the breadth of a finger above the great trochanter. At this point a long narrow-bladed knife is pushed in until it reaches the neck of the femur, and is then passed on in front of the neck, close to the bone. This incision is to make a passage for the Adams saw, which should be introduced alongside of the knife before the latter is withdrawn. The neck is then sawn through from before backward, at right angles to its long axis. Care should be exercised to avoid cutting the neck obliquely. This operation is not applicable to cases in which the neck has been destroyed or deformed; and inasmuch as in a large proportion of the cases of tuberculous

FIG. 302.—OSTEOTOMY OF THE UPPER END OF THE FEMUR.

A, Osteotomy of the neck (Adams); *G*, subtrochanteric osteotomy (Gant); *V*, intertrochanteric osteotomy (Volkmann).

FIG. 303.—OSTEOTOMY OF THE LOWER END OF THE FEMUR.

W, Supracondyloid osteotomy (Macewen); *O*, oblique division of the inner condyle (Ogston).

ankylosis the neck of the bone has been destroyed, the field of the operation is limited. The operation is done with the osteotome through a small longitudinal incision just above the apex of the great trochanter. The osteotome is carried down to the neck of the bone, rotated to the position of a right angle to it, and the bone divided with a few strokes of the mallet.

Subtrochanteric osteotomy (Gant's operation, Fig. 302, *G*) is done through a longitudinal incision on the outer side of the thigh 1 inch to 1½ inches below the great trochanter. The bone should be divided at a right angle just below the lesser trochanter, put up in extension in the corrected position, and treated as a fracture of the thigh. Volkmann's operation divides the bone between the greater and lesser

trochanters (Fig. 302, *V*). Volkmann has devised another operation by which he rounds off the upper end of the lower fragment, scoops out a cup-shaped depression in the great trochanter, and by passive motion secures a joint at this place. The value of this operation is still in question.

The operations of Adams and Gant are usually employed for the correction of deformity following ankylosis of the hip in a faulty position, the latter having the wider range of usefulness. In all of these operations tenotomy and division of contracted soft parts is often required to secure the best results.

Osteotomy of the Lower End of the Femur.—This operation is required usually for knock-knee and for deforming ankylosis of the knee-joint.

Osteotomy for knock-knee (genu valgum) is performed in all adult cases requiring treatment and in aggravated cases in children. If the case remains aggravated by the fourth year operation is advisable. In the normal femur the epiphyseal line is on a level with the tubercle of the adductor magnus muscle and crosses the bone horizontally. In knock-knee this line is oblique, but still parallel with the articular surface, because genu valgum is due to a lateral overgrowth of the diaphysis and not of the epiphysis.

Supracondyloid Osteotomy of the Femur from the Inner Side (Macewen, Fig. 303, *W*).—This is the most generally employed of the osteotomies for knock-knee. The patient lies upon his back with the knee and thigh flexed and the thigh supported on a sand-bag on its outer side. If operating on the right leg the surgeon stands to the outside; if on the left leg he stands opposite the left hip. A short incision is made on the inner side of the thigh ½ inch anterior to the tendon of the adductor magnus and ½ to ¾ inch above the adductor tubercle. This should bring the middle of the incision on a transverse line drawn about a a finger's breadth above the external condyle. The knife is passed to the bone, and before it is withdrawn the osteotome is inserted. The osteotome is then rotated and the bone divided transversely above the epiphyseal line. In doing this it is well to begin with osteotomy on the postero-internal aspect of the bone, driving the osteotome forward and outward. The cut is then advanced to the inner side and then toward the front of the bone. The osteotome is rocked up and down in order to widen the cut. The posterior and outer parts of the circumference remain undivided, and are fractured after the osteotome has advanced through three-fourths of the bone. This operation may be done through a transverse incision, which makes the manipulation of the osteotome easier. After the bone is divided the wound is covered with a small dressing and the limb put up in the corrected position in plaster-of-Paris. The splint should be applied for about four weeks, and the child may be allowed to stand on the leg in about six weeks.

Supracondyloid Osteotomy of the Femur from the Outer Side (Fig. 303, *W*).—The patient lies upon the back with the thigh and the knee flexed

upon a sand-bag. The thigh is adducted and an assistant steadies the leg. A longitudinal incision not longer than 1 inch is made 1 or 2 inches above the external condyle. This incision is made on the outer side of the thigh. It is carried through the iliotibial band down to the bone in front of the tendon of the biceps. The osteotome is inserted, rotated to the transverse position, the bone divided through about three-fourths of its thicknesses, and the division completed by fracturing it. The limb is then put up straight in the corrected position.

Oblique Division of the Internal Condyle (Ogston, Fig. 303, *O*).—The point of a narrow-bladed knife is passed into the bone on the inner surface of the thigh about 2 inches above the adductor tubercle. The point of the knife, with the cutting edge against the bone, is passed forward, downward, and outward till the groove between the front of the condyles

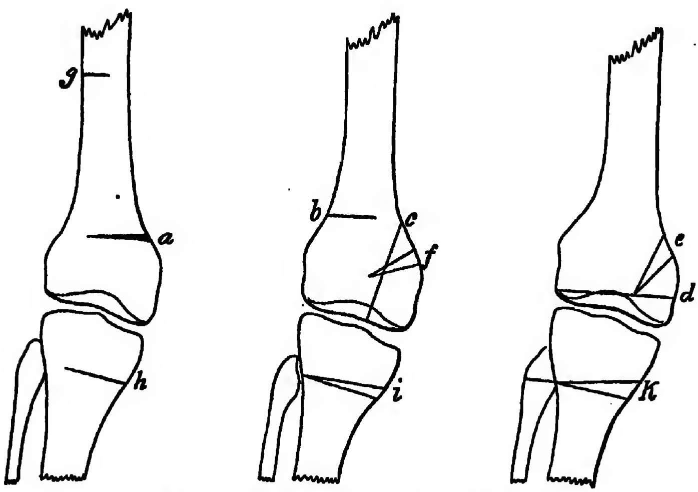


FIG. 304.—LINES OF OSTEOTOMY ABOUT THE KNEE-JOINT.

Osteotomy of both condyles for knock-knee (Annandale, *d*); wedge-shaped osteotomy of the inner condyle (Macewen, *e*); wedge-shaped osteotomy of the inner condyle (Chiene, *f*); linear osteotomy of the shaft of the femur (Reeves, *g*); linear osteotomy of the tibia (Billroth, *h*); wedge-shaped osteotomy of the tibia (Mayer, *i*); osteotomy of the tibia and fibula (Schede, *k*).

is reached. The joint is opened by this incision. A fine saw is passed down in front of the bone at the junction of the inner condyle and the shaft, and the bone is sawn through obliquely. This operation may be done even more easily with the chisel. The inner condyle is completely detached, and by adducting the leg it is displaced upward and the genu valgum corrected. This operation has the decided disadvantage of opening the joint and of involving the epiphysis.

Other operations of less frequent utility are the following (Fig. 304):

Osteotomy of the Tibia.—Osteotomy of the Tibia below the Tuberosities (Fig. 304, *h*, *i*, *k*).—This operation is required to remedy the deformities following rickets, causing knock-knee, bow-legs, or other distortions; and to correct the deformity of vicious union of fractures; and for deforming ankylosis of the knee. The bone is

exposed on its internal surface just below the tuberosity by a longitudinal or transverse incision, and divided from within outward by the osteotome. To prevent injury of the popliteal structures a thin, flat retractor may be passed across the posterior surface, close to the bone. There is less danger of injury to the peroneal nerve if the fibula is also divided, and still less danger if a cuneiform osteotomy of the tibia is done.

Osteotomy of the Shaft of the Tibia.—This operation is indicated for extreme curvatures and in cases in which osteoclasis is not indicated. A short incision is made over the internal surface of the bone at the level of the deformity, the soft tissues dissected up for a short space, the bone partially divided with the osteotome, and fractured. In extreme deformity a wedge-shaped osteotomy, or osteotomy in two places, may be required. An actual lengthening of the bone is produced if the division of bone is made on the concave aspect of the deformity, for in producing the fracture and straightening the bone the gap made by the osteotome is widened. Tenotomy of the Achilles tendon is sometimes required.

EXCISIONS AND RESECTIONS OF BONES.

Excision and Resection of the Upper Jaw.—These operations are usually understood to involve but one of the superior maxillæ, although the simultaneous removal of both bones is sometimes required. Excision of the upper jaw is done on account of malignant tumors of the bone or antrum of Highmore, osteitis, and necrosis. Temporary osteoplastic resection is done to give access to the nasopharynx for the removal of tumors of that region. The bony connections which have to be divided by instruments are—(1) the nasal process, (2) the malar process, and (3) the hard palate and alveolar process. The connections with the other bones of the skull are not so strong that they need be cut. The operation is essentially a very bloody one. Many surgeons employ primary tracheotomy and the tampon cannula, or tamponing the pharynx or larynx to prevent blood entering the trachea, the head being slightly flexed upon the chest or extremely extended. A much better procedure is the temporary or permanent ligation or temporary clamping of the external carotid artery. When this is done the chief difficulty of the operation is removed and excision of the upper jaw becomes a simple procedure. The contrast between the old bloody operation and the ease of the procedure after ligation of the external carotid is very striking. If occlusion of the carotid is not practised, the hemorrhage is best controlled by packing with iodoform gauze, and making firm pressure immediately after the removal of the bone. (See Surgery of the Mouth, Teeth, and Gums, Vol. III., p. 650.)

Many of the operations upon the face call for incisions at acute angles. Such incisions leave sharp points of skin to be sutured. I have found it more satisfactory, for cosmetic reasons, to avoid making these sharp points and to make curved incisions instead. The curve lends itself better to suturing.

Excision of the Upper Jaw by the Mediolateral Incision (*Nélaton, Weber, Fergusson* (Fig. 305, *A, B, C*).—The patient lies with his head turned toward the sound side. The anesthetic mask is removed and the administration of the anesthetic continued through a tube inhaler, or the chloroform mask is reapplied during the operation when necessary. An incision is begun ½ inch below the inner canthus of the eye and is carried down along the side of the nose to the ala, around the ala in the groove where it is joined to the face, thence horizontally

FIG. 305.—LINES OF INCISION FOR OPERATIONS ON UPPER AND LOWER JAWS.
ABC, Mediolateral incision (Nélaton); *E*, external incision (Ollier); *D*, external incision (Velpeau); *IC*, median incision (Dieffenbach); *PRS*, Boeckel's operation; *VW*, incision for temporary division of the lower jaw; *WXZ*, incision for resection of lower jaw.

to the septum nasi, and then directly downward to the free border of the lip. This incision is supplemented by one passing from its upper end outward beneath the eye, directly on the lower border of the orbit, and terminating ½ inch below the external canthus. These incisions should lay open all of the soft tissue down to the bone. The flap representing the soft tissue of the cheek is dissected from the upper jaw, so that the malar process is exposed. The nasal cartilage is separated from the edge of the bone. The periosteum at the lower margin of the orbit is incised and with a thin sharp elevator lifted up from

the orbital surface of the bone. The wire-saw or chain-saw is then passed through the sphenomaxillary fissure and the malar process divided (Fig. 306, *B*). The nasal process is then divided with the bone-cutting forceps. The mucous membrane and periosteum of the hard palate are divided transversely opposite the last molar tooth, and in the median line from this incision forward. The soft palate is then separated from the hard palate through the transverse incision by means of the elevator. The middle incisor tooth is drawn and the hard palate divided by the saw, chisel, or forceps, close to the septum. The mucous membrane lining the cheek is then cut from the alveolar

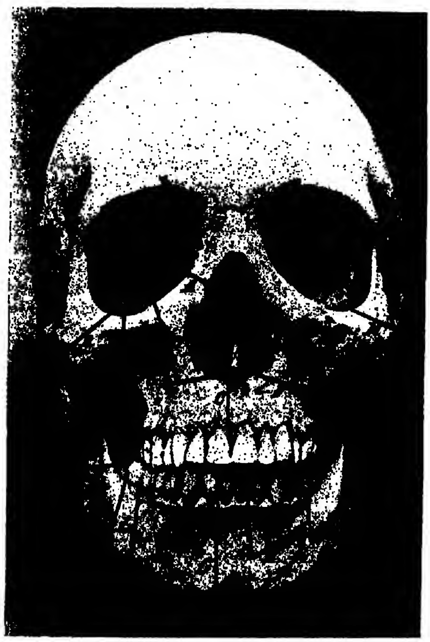


FIG. 306.—LINES OF DIVISION OF BONE IN RESECTIONS OF THE UPPER AND LOWER JAWS. *ABC*, Excision of the upper jaw; *B*, *K*, different points of external division; *EC*, resection of the lower segment of the upper jaw (Guérin). (The line *C* should fall on the side of the nasal septum toward the bone to be removed.) *FM*, Resection of the upper segment of the upper jaw; *D*, resection to gain access to the nasopharynx (Boeckel); *H*, resection of the alveolar process; *G*, excision of half of lower jaw; *L*, osteotomy for ankylosis of lower jaw.

process with curved scissors. Lion-jaw forceps then grasp the bone, and by a rocking motion it is loosened from its remaining attachments, which are the palate bone behind and the ethmoid bone above (Fig. 307). The superior maxillary nerve, emerging in the fissure, should be divided as far back as possible. The divided reflection of mucous membrane is sutured behind to the palate and in front to that of the opposite side. The skin wound and the divided lip are carefully approximated, and the cavity from which the bone was removed is packed with iodoform or balsam gauze.

If the disease does not involve the mucous membrane of the hard palate, the operation should be modified as follows: An incision should

be carried through the mucous membrane and periosteum of the hard palate close to the alveolar process of the diseased bone instead of in the median line. The valve of soft tissue should be elevated, and when the bone is removed this may be sutured to the edge of mucous membrane of the cheek and the nasobuccal septum retained complete (Fig. 308).

Another point which I have found most useful in cases in which the disease has not extended toward the malleolar process is to saw the outer part of the bone forward in such a way that all or a large portion

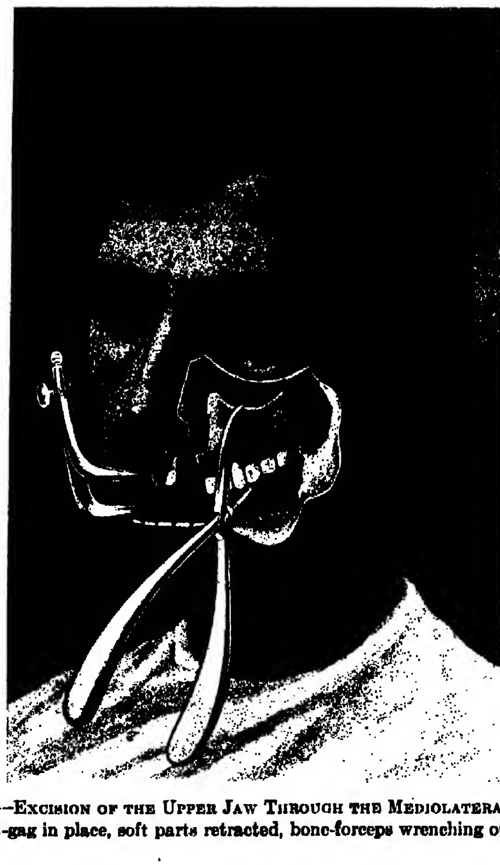


FIG. 307.—EXCISION OF THE UPPER JAW THROUGH THE MEDIOLATERAL INCISION. Mouth-gag in place, soft parts retracted, bone-forceps wrenching out bone.

of this process is left attached to the malar bone. At this location, in sawing from the sphenomaxillary fossa forward, the surgeon has the choice of bringing the anterior end of the bone division inward or outward over a variation of more than an inch. This may depend upon the position of the disease. The more of this process that can be left, the more support and prominence there are for the cheek, and consequently the less the deformity (Fig. 306, *B*, *K*).

Excision of the Upper Jaw by the External Incision (Fig. 305, *D*, *E*).—An incision through the whole thickness of the cheek is carried

upward and outward from the angle of the mouth toward the outer canthus of the eye. The incision may be curved with its convexity outward (Velpeau) or straight (Ollier, Liston). This incision should end over the middle of the malar bone. The soft tissues are then dissected up and retracted from the bone to be removed, the bone is divided, and the operation proceeded with as described above. This incision has the disadvantage that it divides the branches of the facial nerve, and the curved incision is apt to divide Steno's duct.

Langenbeck's operation (Fig. 309, *FGH*) carries an incision from the side of the nose, beginning at the lower end of the suture between the nasal bone and the upper jaw, and curves downward to the juncture of the upper lip and the cheek, and thence upward to end over the middle of the malar bone, thus making a U.

Dieffenbach's operation (Fig. 305, *IC*) is characterized by a median incision beginning at the root of the nose and passing down the median line of the nose and through the lip. To this is added a transverse incision from the upper end of the first to the inner canthus of the eye.

Malgaigne's operation adds a median division of the upper lip to the *external incision* of Velpeau.

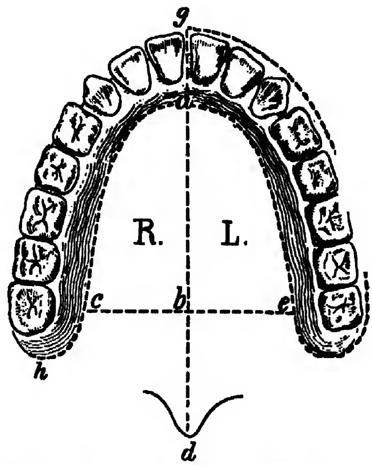


FIG. 308.—MUCOUS MEMBRANE AND PERIOSTEAL INCISIONS.

R, Right; L, left. The incision *abch* is made for excision of the right upper jaw. The bone is divided along the right side of the line *gb*. If there is no disease of the hard palate, the incisions *ach* and *cb* may be made. Ollier's subperiosteal excision is *afg*.

Simultaneous Excision of Both Upper Jaws.—This operation is best done by means of the *external incisions* passing from the angles of the mouth to the middle of the malar bones. The soft tissues lying between these two incisions, together with the cartilages of the nose, are dissected up from the two maxillæ as far as the orbits, and the flap turned up over the forehead. The operation is proceeded with as described above under the *mediolateral incision*, except that the two bones are not separated, but are removed together. The malar processes are divided in the usual manner. The nasal processes may be divided separately by bone forceps or together by passing the wire-saw from one orbit into the other through the lacrymal bones. As much of the periosteum of the hard palate as possible should be saved by employing a curved incision near the alveolar margin and stripping it back, leaving it connected posteriorly. The soft palate is separated from the bone. The bones are then twisted downward and forward from their other attachments. This is a less difficult operation than removal of the single bone, provided, of course, that occlusion of both external carotids has been practised.

Subperiosteal Excision of the Upper Jaw.—This is done through the *external incision,* although the *mediolateral incision* is well adapted to the operation. If necessary, median division of the upper lip may be combined with the external incision of Ollier. In this operation the periosteum is left attached to the overlying soft tissue and is elevated with it. The operation is indicated in cases in which the periosteum is not diseased and in operation for exposure of the nasopharynx. After making the skin incision the mucous membrane is divided by an incision beginning at the median line in front, on the outer surface of the alveolar process, and carried backward, close to the edge of the

FIG. 309.—LINES OF INCISION FOR OPERATIONS ON UPPER AND LOWER JAWS.

FGH, U-incision for resection of upper jaw (Langenbeck); *TO,* incision to gain access to the nasopharynx (Ollier); *NFO,* Langenbeck's osteoplastic resection; *VWX,* incision for resection of half of body of lower jaw; *VWXZ,* incision for resection of half of lower jaw.

gum, around the last molar tooth, and then forward in the same manner on the inside of the alveolar process to a point opposite its beginning (Fig. 309, *g, f, a*). An incision through the periosteum is then carried upward from the beginning of the first to a point just external to the anterior nasal spine. The periosteum is then stripped back from the anterior surface of the bone. When the infra-orbital canal is reached, the nerve is divided at its point of emergence. The stripping-up of the periosteum is continued into the orbit and to the limit of the bone. The lacrymal sac and duct may be left uninjured, adherent to the periosteum. The separation of the periosteum in the roof of the mouth

is continued as far as the median line. The malar process and the nasal processes are divided, the incisor tooth removed, and the chisel used to divide the bone obliquely back to the median line, and thence backward through the rest of the hard palate. The bone is then removed with strong forceps, and, finally, the mucoperiosteal flap from the hard palate is sutured to the periosteal flap above.

Resection of the Lower Segment of the Upper Jaw.—The removal of the bone below the infra-orbital canal by *Guérin's operation* is as follows (Fig. 305, *KM*; Fig. 306, *EC*): A curved incision, with its convexity outward, is carried from the upper part of the wing of the nose to the angle of the mouth, following the curve usually present in this situation. The soft parts and the nose are dissected from the bone and retracted. A saw is passed into the naris, and the bone is sawn horizontally outward, the saw cut ending in the malar process. The soft structures of the palate are divided transversely, as described above, and the hard palate near the middle line, and the bone twisted out. This procedure lends itself to the subperiosteal operation. It gives a good view of the nasopharynx and is indicated for disease of the bone not involving the orbital plate.

Resection of the Upper Segment of the Upper Jaw (Fig. 306, *FM*).—For this operation the best incision is the *mediolateral*. The soft parts are raised from the bone and the periosteum is detached from the orbital plate. The malar and nasal processes are divided as already described, and a horizontal cut made with the saw from the naris outward, passing above the alveolar process. The bone thus freed is wrenched out.

Osteoplastic Resection of the Hard Palate (Fig. 309).—This operation is done to give access to the nose or nasopharynx. The posterior portion is resected by carrying a median incision through the soft palate and mucous membrane and periosteum of the hard palate, as far forward as is desired. A transverse incision is carried from the front of this to one or both sides, and the mucoperiosteal flap separated from the bone. The mucous membrane on the floor of the nostril is divided close to the septum and pressed back. As much of the hard palate as is necessary is then removed. This may involve one or both sides; if the latter, the vomer is divided with forceps. The operation is completed by suturing the soft parts back in place.

Osteoplastic resection of the anterior portion of the palate is accomplished by extracting the canine teeth, dissecting the upper lip away from the bone until the nasal cavity is exposed, and then dividing the alveolar process and the hard palate by two lines of parallel incisions running from the canine sockets back to the soft palate. The vomer is divided and this bone-flap, attached posteriorly, is turned down. It may be replaced and sutured in position at the close of the operation.

Operations through the Upper Jaw to Gain Access to the Nasopharynx.—Subperiosteal operation through the upper jaw, described above, is the most satisfactory for securing free access to the naso-

pharynx. Temporary resection of the upper jaw is done by means of an osteoplastic flap having its base at the nose and its apex over the malar bone, and leaving the alveolar process and hard palate (Langenbeck, Fig. 309, *NFO*).

Boeckel's operation is a valuable procedure (Fig. 305, *PRS;* Fig. 306, *D*). An incision is carried from the root of the nose, curving downward along the side of the nose to the wing of the nostril, and thence outward upon the cheek. A second incision begins at the origin of the first and curves downward and outward along the lower margin of the orbit to the infra-orbital foramen, avoiding the lacrymal sac. This flap is raised with the periosteum. A pyramidal section of the upper jaw is then removed with the chisel, having the outer border of its base marked by a vertical line just internal to the infra-orbital foramen, and the base representing the rest of the anterior surface of the bone above the alveolar process. This mass bears the middle and inferior turbinated bones.

The *operation of Ollier* (Fig. 309, *TO*) begins with an incision external to the ala which passes upward to the middle line at the root of the nose, at the level of the inner canthi of the eyes; a similar incision is made on the other side, making an inverted V. The bone is sawn through in the line of incision and the nose turned down as a flap. The septum is removed or pressed aside, the nasopharyngeal condition dealt with, and the operation continued by replacing the nose and suturing it in place. This operation may be modified for the removal of a large tumor by making the angle greater between the two arms of the V and carrying the lower extremities of the incision farther away from the alæ.

The *operation of Annandale* divides the mucous membrane at the lip-alveolar junction, dissects up the nose from its bony attachments, divides the alveolar process and hard palate near the median line, and pries apart the divided bones to increase the space of access.

Denker's operation[20] for reaching malignant tumors laterally does not divide the skin. The soft tissues of the mouth are widely retracted and an incision through mucosa and periosteum is carried along the alveolar process from the last tooth horizontally forward, nearly to the middle line, and thence up to the apertura pyriformis. The periosteum is elevated as far up as the lower border of the orbit and the nasal opening, and retracted upward. The bone is then removed from the nasal margin, opening the antrum and continuing as far outward as necessary.

Resection of the alveolar process (Fig. 306, *H*) is practised for the removal of limited disease, such as epulis. The section to be removed should be marked out and denuded of healthy mucous membrane and periosteum. Teeth which are in the way should be removed, and the anterior and posterior limits of the resection defined by the saw. The upper ends of the saw cuts are connected by a line marked with the chisel, or the horizontal division may be made with a saw. The rongeur is useful in extending the operation in the direction of any suspected disease.

Excision and Resection of the Lower Jaw.—The whole or any part of the lower jaw may be removed. Operation is usually performed for tumor or necrosis, and involves only a part of the bone. The surgeon should spare as much of the bone as possible, and should not endeavor to perform a typical operation, but should suit each operation to the requirements of the case. The extent of the incision should vary with the amount of bone to be removed. The important structures lying close to the bone to be borne in mind are the facial and internal maxillary arteries, the facial and lingual nerves, and the submaxillary and parotid glands and their ducts. Healthy periosteum and mucous membrane should be preserved as far as possible. Operations, removing the body of the bone, require detaching from their anterior supports the muscles holding the tongue and thus permitting it to drop back upon the glottis; a suture, therefore, should be passed through the tongue to hold it forward during the operation. After the operation as perfect a suture as possible should be made, uniting the buccal mucous membrane.

Resection of Half of the Body of the Lower Jaw (Fig. 305, *VWX*).—A median incision is made from the junction of the lower lip and the chin downward to a point just below the symphysis under the chin. It is not necessary to divide the lip, although it is commonly done. Another incision is carried along beneath the jaw as far as the angle. The facial artery is ligated and the bone uncovered. If free of disease, the mucous membrane and periosteum are divided close to the teeth, inside and outside, and stripped down with an elevator. A tooth is drawn and the jaw divided anteriorly with a wire-saw. The side to be removed is retracted forward, and the separation of the periosteum and muscles completed. Division as far posteriorly as necessary is then made, the bone is removed, and the mucous membrane covering the defect is tightly sutured with the view of preventing saliva entering the wound. The wound should be closed with drainage at its posterior part.

This operation may be done with simply a vertical incision in the middle line, or with the horizontal incision under the jaw alone, or through the mouth without any skin incision. In dividing the bone it is well, if possible, to make the division a little to one side of the median line, in order to preserve the insertion of the geniohyoglossus muscle. The incision to be employed will depend much upon the extent and location of the disease to be removed.

Resection of Half of the Body and the Ramus of the Lower Jaw (Fig. 305, *VWXZ*).—The median incision is made and continued, as above, horizontally along the lower border of the jaw to the angle, and thence upward to the level of the lobe of the ear, ending short of the main fibers of the facial nerve. The bone is then uncovered through this wound, externally and internally, as far as the mucous membrane. The jaw is then divided anteriorly and retracted outward. The division of the mucous membrane and the muscles is next accomplished, and the inferior dental nerve divided. The ramus is denuded

of its soft tissues with the elevator, and, as the jaw is forcibly depressed, the attachment of the temporal muscle to the coronoid process is divided by means of curved scissors. A small round retractor passed close to the bone and drawn strongly upward protects the facial nerve from being wounded. The head of the bone is then easily twisted out of the glenoid fossa. The internal maxillary artery, lying close to the neck of the condyloid process, should not be injured. The closure of the soft parts is described above.

Excision of the Whole of the Lower Jaw.—This operation is done through an incision extending around the border of the jaw from a point opposite the lobe of one ear to the other. The jaw should be divided in the middle and each half removed separately.

Resection of the alveolar process (Fig. 306, *H*) is accomplished without a skin incision just as described for the upper jaw. An effort should always be made to preserve the continuity of the jaw.

Temporary Division of the Lower Jaw (Fig. 305, *VW*).—This operation is undertaken when it is desirable to render more accessible the floor of the mouth, the palatine arch, the tongue, the nasopharynx, and the base of the skull. The division may be made laterally or in the middle and the bone segments retracted.

The Median Operation (*Sédillot*).—An incision is made in the median line and under the chin, the point of a narrow knife is then passed behind the symphysis and brought out through the frenum of the tongue close to the bone. A middle incisor tooth is extracted and the bone divided with a wire-saw. Retractors may then be used to separate the bone and give access to the floor of the mouth, the sublingual gland, and the tongue. The bone is united with silver wire.

The Lateral Operation (*Langenbeck*).—An incision passes downward from the angle of the jaw to the level of the larynx. The details of the rest of the procedure are the same as for the median operation. This gives access to the posterior portion of the tongue, the palatoglossal arch, the pillars of the fauces, and all of the pharynx.

Resection of a segment of the lower jaw may be practised to give a larger opening than is secured by either of the above operations.

Operations for Ankylosis of the Lower Jaw.—Ankylosis, due to the formation of scar tissue along the ramus of the jaw as a result of inflammatory disease, is treated by osteotomy and the formation of a false joint.

Esmarch's operation (Fig. 306, *L*) consists in the removal of a wedge-shaped piece of bone from the portion of the body lying just in front of the masseter muscle. This is done through an incision along the lower border of the jaw. If the adherent tissue does not extend the full length of the ramus, it is better to make a horizontal section of the ramus and prevent bony union by constant motion. This operation can be done by a chisel passed through the mouth to the ramus, or the bone may be exposed by an external incision.

Excision of the condyle is performed when the ankylosis is due to

conditions within the joint. A vertical incision is made just in front of the temporal artery, beginning at the zygoma and ending above the facial nerve, which emerges on a level with the lobe of the ear. This incision, if necessary, may be supplemented by a second one at right angles to its upper end and passing along the lower margin of the zygomatic arch. The joint is opened, the neck of the condyle divided, and the head of the bone removed. The parotid gland, the internal maxillary artery, and the facial nerve should be avoided. Passive motion is necessary to supplement the operation, even though it must be practised under an anesthetic. Operation on both sides is performed the same as above.

Prosthetic Apparatus to Remedy Defects after Resection of the Jaws.—Many contrivances have been devised to correct deformities following removal of the whole or parts of the jaw-bone. The most successful are made of hard rubber, having approximately the size and shape of the bone removed, and carrying teeth corresponding to those missing. Two important problems confront the surgeon—the rapid contraction of the parts after removal of the bone, and the difficulties of retaining in place such prosthetic appliances. The first of these is met by the introduction of prosthetic apparatus as early as possible after operation, before cicatricial contraction has advanced. The perfection of this branch of surgery is in the hands of the prosthetic dentists, who have devised means for the retention of these apparatus.

Deformities which for some reason are not remedied in this manner may be improved, at least so far as the appearances of the face go, by the injection of paraffin to fill out the sunken features.

FIG. 310.—PLATE WITH "PLUMPER," WORN AFTER RESECTION OF UPPER JAW.

Prosthesis of the Upper Jaw.—After resection of the alveolar process a rubber denture, built up to fit the jaw, serves most satisfactorily. For removal of the upper jaw the dentist should make an impression of the mouth before operation. With this as a guide he should construct an upper plate which should be inserted within a week after the operation. This primary plate need not have teeth upon it, but is intended to keep the parts patent while the wound is cicatrizing and the surfaces are becoming covered with epithelium. A permanent plate should be made, embodying any modifications for comfort which the first plate has suggested, and also supplying the missing teeth and, most important, having on its upper surface a "plumper." This "plumper" is a projection or protrusion, built upon the plate, to supply the defect of the missing bone. It may be made as a hollowed depression on the plate. It is not necessary that it should be large; indeed, if it is not put in immediately after the

operation there will be but little room to accommodate it. Fig. 310 shows a plate which is worn by a man whose upper jaw I removed a year ago. Although this "plumper" is small, there is scarcely a noticeable deformity, and mastication is accomplished satisfactorily on the sound side.

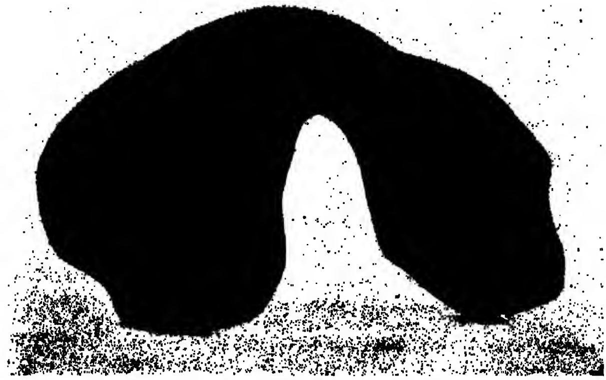


FIG. 311.—PLATE WORN AFTER REMOVAL OF BOTH UPPER JAWS.

The greatest difficulty is experienced after removal of both upper jaws. Here it is imperative that the prosthesis should be inserted early, as contraction is rapid. Fig. 311 shows a plate which is worn by a man from whom I removed both upper jaws entire, nine months ago. This plate is much narrower than the normal mouth, but still

FIG. 312.—INTERDENTAL SPLINT, TO BE WORN IMMEDIATELY AFTER REMOVAL OF HALF OF LOWER JAW.
A, opening corresponding to bone removed.

gives a decided sense of tension. Such a device serves as a septum between the oral and the nasal cavities. It is held by the muscles of the cheeks, and may have some front teeth added for cosmetic effect. Such plates may be attached by springs to the back teeth of the lower jaw.

Prosthesis of the Lower Jaw.—The defect in the lower jaw usually requiring to be remedied is that which follows resection of half of the body. This operation is usually done when either the teeth are absent or the jaw is distorted by disease and an "impression" for reproduction cannot be made; however, the skilful dentist can take an "impression" of the mouth and judge the normal state of the diseased jaw from the upper teeth of the diseased side and from the lower teeth of the sound side. From this the prosthetic apparatus is made. Before the operation an interdental rubber splint should be made, having a defect at the lower part representing the situation of the bone to be removed (Fig. 312). Food can be taken through this opening. This splint should be inserted as soon as possible after the operation, and the jaws bandaged together. The object of the splint is to keep the unopposed remaining half of the jaw from the inward displacement which will inevitably result without it. This splint is very important, and after it is applied the ordinary bandage of the jaw should not be trusted, but adhesive strips should be incorporated in the bandage to make it secure and immovable. In a few days, after the traumatic irritation has subsided, the prosthetic "plumper" should be inserted. The device which has been found most serviceable for this purpose is a modification of that described originally by McBurney.[21] It consists of a hard-rubber body, bearing teeth, and fitting the gap from which the bone was removed. It is attached at its inner end to a metallic shaft or plate which is fitted to lie against the inner surfaces of the remaining teeth of the other half of the jaw (Fig. 313). Offsets from this shaft fit into the spaces between the sound teeth to prevent backward and forward movement. The construction of this arm will vary in each case as the ingenuity of the dentist finds the best means of securing a fastening. Capping two teeth and constructing a bridge to which the arm can be articulated has proved practicable. A cap, fitting over a capped tooth in the lower jaw, and another cap over the back tooth in the upper jaw and connected to the prosthesis by a spring, have been successfully employed to hold the prosthesis in place. If the ramus has been removed, the "plumper" should have added to it a short projection rounded at the top to partly take its place. This whole apparatus is smaller than the bone removed. A better final result is often secured by making an impression of the defect and constructing the "plumper" after this pattern. It is most expedient to make the first as a temporary "plumper," without teeth, to be worn until the parts have become adapted to the new conditions, when a

FIG. 313.—PROSTHESIS, CARRYING FOUR TEETH, INSERTED AFTER REMOVAL OF HALF OF THE LOWER JAW.

permanent one embodying the necessary modifications can be made. The important point is that it should be introduced as early as possible and not left out, for contraction which cannot be overcome quickly takes place. It is also important that such apparatus should be easily removable for the sake of cleanliness. It is for this reason that, where the capping of teeth is resorted to, the apparatus should not be fixed to the permanent caps, but to caps which can be slipped over them. The artificial teeth are entirely cosmetic.

In cases in which a section of the jaw is removed, leaving teeth on either side of the defect, the prosthetic problem is a much easier one. Here the space is filled with a gold bridge bearing a hard rubber body. After removal of the whole lower jaw the prosthetic apparatus must be attached to the back teeth of the upper jaw. Such an apparatus is constructed by mounting gold-plated springs upon caps on these teeth and joining the false jaw to springs.

Excision of the Clavicle.—Excision of the clavicle is a serious operation because of the close proximity of this bone to the large vessels of the neck, their tributaries, and the cords of the brachial plexus. Behind and below the bone lie the innominate, subclavian, and jugular veins; the subclavian, suprascapular, and internal mammary arteries; the cords of the brachial plexus; the pneumogastric nerve; and the thoracic duct. The veins particularly, lying so close to the bone, are prone to become involved by the disease and require excision.

Operation.—No rules can be laid down for excision for tumor, as the operation is proceeded with without reference to the bone. When excision for other disease is practised, it is desirable to make a subperiosteal operation. An incision is made along the anterior margin of the bone, exposing the affected parts. The periosteum is divided in the same line. A short incision is made at right angles at the end of this incision. These periosteal flaps are turned up with the elevator and the separation continued as far as possible around the bone. The bone is then divided and the separation completed.

When the whole bone is to be removed for necrosis, the incision is continued beyond its extremities. The periosteum is divided in the same line and separated from the bone by the elevator. At the junction of the outer and middle thirds a wire-saw is carefully carried around the bone, or it is divided with the bone-cutting forceps. The inner end of the outer fragment is grasped by forceps and drawn forward, while it is cleared of periosteum posteriorly and below. This is removed, and the inner segment is dealt with in the same way. This sternal segment lies over the structures mentioned, and much care is advised in its removal. The elevator and knife should be kept close to the bone. The soft parts should not be dragged upon, and the vessels should be protected with a flat retractor. The wound should be closed, according to the rules laid down for the operative treatment of osteomyelitis, and the arm put up as in fracture of the clavicle.

Excision of the Scapula.—Resection of parts of the scapula must meet the peculiar indications of each case; no rules can be laid down.

Excision of the whole bone is done after the following method (Fig. 314, *A*): The patient lies on the sound side. An incision is made along the spine and the acromion process. This joins an incision made along the vertebral border, which need not be as long as the bone. The flaps are turned back, and the muscles attached to the spine and acromion are divided. The periosteum of the inner border is divided between the rhomboideus and the infraspinatus muscles, and the infraspinous fossa denuded of periosteum, carrying the muscle. If the marginal cartilage is not completely ossified, it should be left adherent to the periosteum. The supraspinous fossa is then cleared, care being taken not to injure the suprascapular nerve passing through the notch, but to raise it up with the periosteum. The lower angle of the bone is freed by detaching the teres major and serratus magnus, the bone is lifted away from the thorax, and the subscapularis dissected off from below upward. The denudation is continued and the bone is lifted away. If the disease permit, it is desirable to stop the denudation at the neck of the scapula, which is divided with the saw. If all of the processes have to be removed, the joint should be open from below and its ligaments divided. The acromion and coracoid processes are divided from their attachments and the bone removed. If possible, the coracoid process should be preserved by dividing it at its base and leaving it in place. The detached muscles and periosteum should be anchored in position with a few stay sutures.

FIG. 314.—POSTERIOR VIEW OF SHOULDER. *A*, Excision of scapula; *K*, posterior skin incision for excision of shoulder-joint (Kocher).

Treves preferred to reverse this operation and divide the external attachments first and finally free the vertebral borders. Velpeau made an incision along the spine of the scapula, another starting from the anterior extremity of this and running toward the root of the neck, and a third starting from the same point and running toward the axilla behind. Syme advised two incisions crossing near the center of the bone. The vessels requiring attention are the posterior scapular, the suprascapular, and the subscapular arteries.

Excision of the Head of the Scapula.—When the head of the scapula is to be resected, without operation on the humerus, the operation is carried out through a posterior incision extending from the base of the acromion process downward to the posterior fold of the axilla.

Resection of the Humerus.—In operations upon the humerus

it is most important to bear in mind the position of the musculospiral nerve, which traverses its upper and middle posterior surface obliquely from above downward and outward between the external and internal heads of the triceps, and passes down the outer side at the lower third of the arm, between the brachialis anticus and the supinator longus.

Excision of the Head of the Humerus.—(See *Excision of Shoulder-joint*, p. 775.)

Excision of the Shaft of the Humerus.—An incision is made along the posterior border of the deltoid and the outer edge of the biceps. The outer border of the brachialis anticus is discovered and followed down to the bone. The musculospiral nerve lies posterior to this, and it is wise to identify it and draw it aside. To prevent shortening some bone should be left, if possible.

Excision of the Lower Extremity of the Humerus.—(See *Excision of Elbow*, p. 777.)

Total excision of the humerus is accomplished through a combination of the incisions recommended for the other parts of the bone.

Excision of the Ulna.—This bone is quite superficial and easily removed. A longitudinal incision is made along its posterior aspect. At the upper end the incision should be made obliquely outward and upward between the triceps and anconeus muscles. Subperiosteal excision should be employed as far as possible. The triceps is retracted to the inner side and the olecranon freed. After the bone is exposed throughout, the operation is facilitated if it is divided in the middle and the halves removed separately. The posterior branch of the ulnar nerve passes back beneath the flexor carpi ulnaris about 2½ inches above the lower end.

Excision of the Radius.—The incision in the skin is made from the styloid process of the radius, along the outer side of the forearms, to the radiohumeral articulation. The supinator longus is exposed at its posterior border and the bone is approached below, between it and the extensor tendons of the thumb, and above, between it and the two extensores carpi radiales. Coming down upon the supinator brevis, it is divided longitudinally, and the bone is exposed. The periosteum is opened and detached, the bone divided in the middle, and each half separately removed. For excision of a part of the bone, incision along this same line is used.

Excision of the Carpal Bone.—(See *Excision of the Wrist*, p. 786.)

Excision of the Metacarpal Bones.—The metacarpal bones are best exposed by longitudinal dorsal incision over the bone to be excised. This incision should involve only the skin. The tendons and their sheaths crossing the bones should be drawn aside. The bone is exposed, its periosteum divided longitudinally, and stripped from the bone, the bone should be cut in two with forceps, and each half removed, care being taken not to open the joints. Good results may be secured if the metacarpophalangeal joint is not destroyed, and if long axis traction upon the finger is maintained to prevent its retraction upward.

Excision of Phalanges.—The incision should be made on one side or the other of the extensor tendons. In the case of a terminal phalanx the incision should be made more laterally, and pass around the end of the finger, close to the nail, in the shape of a U. If the periosteum can be preserved in the case of young persons and extension maintained, excision of the phalanges is indicated, but otherwise amputation is to be preferred, except in the case of the thumb, and here excision is always to be preferred, even though the periosteum cannot be preserved.

Resection of Vertebræ.—(See chapters on the *Surgery of the Spine* and on *Orthopedic Surgery*, Vol. II., pp. 870 and 490.)

Resection of the Bones of the Pelvis.—No rules for incision can be given for resection of the pelvic bones. Commonly but a portion of a bone requires resection, and this is best reached by incision over the disease. The whole of certain pelvic bones has been removed. Ollier removed the ascending ramus of the ischium and most of the pubic bone through an incision 4 inches long, extending from the genitocrural fold toward the pubes. Nélaton did an excision of the whole ilium with good results. For removal of the ilium the incision should follow the crest, and at the anterior superior spine turn downward and backward toward the back of the great trochanter. The periosteum is divided along the crest and separated from the iliac fossa and externally. The separation may be carried as far as necessary and the bone removed.

Excision of the Coccyx.—This operation is done for coccygodynia for injury of the coccyx, to facilitate approach to the rectum, and for imperforate anus. An incision is carried in the median line from the tip of coccyx to its base, a finger in the rectum determining the exact position of the bone. In fat persons this incision may be supplemented by a transverse incision at its upper end. The bone is denuded posteriorly and laterally, the sacrococcygeal joint opened, the bone separated from the sacrum, the upper end grasped by the forceps, and the bone drawn out while its anterior attachments are divided.

Resection of the Femur.—Resection of a portion of the shaft of the femur is done for necrosis. (See *Operations for Osteomyelitis*, p. 735.) The bone is best approached on the outer side through a longitudinal incision. The bone is reached between the vastus externus and the short head of the biceps. The muscles are strongly retracted, the periosteum stripped back as far as possible, and the desired segment removed. If there is no involucrum, in the case of adults the two ends must be brought together and secured; in the case of children, extension should be made with the hope of bone developing from the intervening periosteum.

Disease of the lower extremity of the femur, with sinuses in the popliteal region, is best reached by lateral incision passing down to the bone in the course of the intermuscular septum. The posterior aspect of the bone is easily reached in this manner, and the popliteal structures left posteriorly to the field of operation.

Resection of the Tibia.—This operation is done usually for necrosis following osteomyelitis or compound fracture. The location of sinuses should govern the place of approach, although it is most desirable to uncover the bone by a longitudinal incision just in front of its inner border, avoiding the internal saphenous nerve. When the posterior surface is to be reached, the incision should run along the inner border of the bone, and when the external surface is to be reached, the incision should be made just external to the anterior border. The periosteum, having been divided longitudinally, should be elevated. As sound bone is approached above and below, in stripping back the periosteum, it is well to divide it transversely in order to save stripping it from the healthy part of the bone.

When a gap of less than 2 inches exists after the removal of fragments following compound fracture, a similar length may be resected from the fibula. If the gap is a larger one, an osteoplastic operation is better. (See *Osteoplastic Operations*, also *Operations for Osteomyelitis*, pp. 747 and 735.)

Resection of the Fibula.—The fibula is subcutaneous at its upper and lower extremities; the shaft is covered with muscle. In excision of the upper end care should be taken not to wound the peroneal nerve or to open the tibiofibular joint, which usually communicates with the knee-joint. The nerve passes down along the posterior border of the tendon of the biceps, which is inserted into the head, and passes forward along the outer side of the neck of the bone. Before operating on the upper extremity of the bone it is well to locate and mark the position of the nerve before the patient is anesthetized.

Resection of the upper extremity of the fibula is done through a longitudinal incision, begun 1 inch above the head, at the posterior border of the tendon of the biceps, and carried downward as far as necessary behind the bone in the space between the soleus and the peroneus longus muscles, with the view of leaving the peroneal nerve to the outer side. In removing the bone a shell bearing the articular surface should be left, in order to avoid opening the joint. In removal of the whole shaft of the fibula the bone must be approached in two different planes of muscles, one above and one below, and divided in the middle, and each half removed separately. Resection of the lower end is described under Resection of the Ankle-joint.

Excision of the Tarsal Bones.—Excision of the bones of the foot for disease cannot often be done as a typical operation because of the peculiarities of each case. All the disease should be removed, all of the healthy bone should be left—is the principle to guide the surgeon. The character and extent of the operation must depend upon the nature of the disease and the age and condition of the patient. The bones most commonly requiring operation are the calcaneum and the astragalus. Subperiosteal excisions should be practised, if possible. It should be borne in mind that disease of these bones commonly starts in the calcaneum, then involves the calcaneo-astragaloid joint, and then the astragalus.

Excision of the Calcaneum.—Pains should be taken to leave all healthy bone and periosteum. In the subperiosteal operation of Ollier (Fig. 325, *A*) the patient lies on the sound side and the inner side of the foot rests upon the sand pillow. The skin incision begins at the outer border of the tendo Achillis, about 1 inch higher than the tip of the external malleolus. This incision is continued down along the outer border of the tendon below the outer tubercle of the calcaneum, around which it curves, and is then made to pass forward and slightly upward to the upper part of the base of the fifth metatarsal bone. The edge of the tendo Achillis and the plantar muscle are exposed. The bone is then uncovered in the line of the incision, care being taken not to divide the tendon of the peroneal muscles. This incision follows pretty closely the posterior and inferior contour of the bone. The periosteum is then elevated, carrying with it, if necessary, the tendo

FIG. 315.—*A*, Excision of astragalus, external incisions (see Fig. 316, *A*); *B*, excision of ankle-joint, external incision (see Fig. 316, *B*); *F*, excision of calcaneum (Farabeuf).

Achillis. The peroneal tendons are drawn aside, the external lateral ligament detached, and the exposure continued to the desired extent. If the whole bone is to be removed, the calcaneocuboid and calcaneo-astragaloid joints are opened; the interosseous ligament is divided with a long straight bistoury. The bone is then grasped with the lion-jaw forceps and rotated downward, the calcaneo-astragaloid joint is further opened, and the internal lateral ligaments detached. The sheath of the flexor longus hallucis is opened in the operation.

Resection of the posterior portion of the bone is more simple. The incision is not carried so far forward, the periosteum is elevated, and the diseased segment cut out with the saw or chisel.

Farabeuf's Operation (Fig. 315, *F*).—The patient lies in the above-described position. An incision is carried from the base of the fifth metatarsal bone, on the outer border of the foot, backward and around

the heel, and ends about 1¼ inches to the inner side of the middle of the heel. This is met by a vertical incision 2 inches in length, just in front of the outer border of the tendo Achillis. These incisions are deepened and two flaps turned up, care being taken not to wound the peroneal tendons which lie under the anterior flap. The periosteum is incised vertically behind the peroneal tendons and horizontally in front of them. The periosteum with the attached ligaments is elevated from the bone as far as possible, including the tendo Achillis. By retracting the flaps most of the bone can be denuded, and the interosseous ligament divided. The anterior part is then grasped with lion-jaw forceps and abducted. As this is done the periosteum is elevated from the inner surface and the bone removed.

Excision of the Astragalus.—This operation is done for necrosis or caries, and as a step in excision of the ankle. It is no longer done

FIG. 316.—*A*, Excision of the astragalus, internal incision (see Fig. 315, *A*); *B*, excision of the ankle-joint, internal incision (see Fig. 315, *B*); *C*, excision of first metatarsal bone.

for fracture and dislocation, unless necrosis makes it necessary. When removal of a fractured or dislocated segment of the bone is required, it is usually reached best over the most prominent part. Comminuted fragments may be reached through an incision between the extensor tendons of the first and second toes.

For complete removal of the bone the following operations are done (Fig. 315, *A*; Fig. 316, *A*): The patient lies upon the back with the foot extending beyond the end of the table, or the lower third of the leg supported by the sand pillow. An outer incision 2½ inches long is begun just above the lower articular margin of the fibula, and passes downward in front of the external malleolus, just posterior and parallel to the tendon of the peroneus tertius. To this incision is added another at right angles from its middle, which passes backward and downward and ends just below the tip of the outer malleolus.

The two right-angle flaps are turned back and the bone is exposed between the tendons of the peroneus tertius and the peroneus brevis. The foot is then extended and inverted, the tendons retracted, and the ligaments connecting the bone to the tibia, fibula, calcaneum, and scaphoid are divided as far as possible. An inner incision 2 inches long is then made, beginning at the tip of the inner malleolus, and curved upward and forward just in front of the anterior margin of the malleolus. Through this incision the remaining ligaments holding the bone are divided. With the foot extended and inverted, the surgeon now grasps the bone through the outer wound with the lion-jaw forceps and wrenches it out. Verneuil recommends sawing through the neck of the bone and first removing the head.

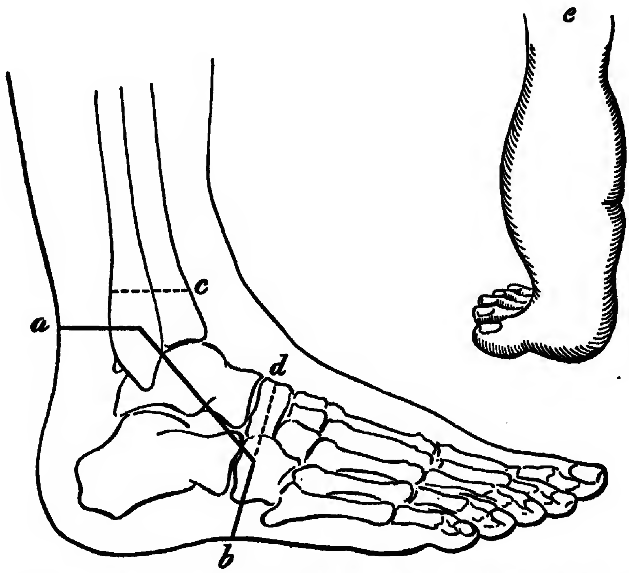


FIG. 317.—OSTEOPLASTIC EXCISION OF THE HEEL AND ANKLE. (Mikulicz.)
ab, Skin incision; *c* and *d*, lines of the division of the bones; *e*, postoperative result.

The *operation of Ollier* (Fig. 325, *B*) consists in a curved incision across the front of the ankle, beginning on the inner side at the point at which the tendon of the tibialis anticus crosses the tibiotarsal articulation, and passing forward to the middle of the scaphoid, and then back to just below the external malleolus. This flap is turned up, exposing the tendons, which are lifted out of their sheaths and retracted. The extensor brevis muscle is detached at its origin, the ligaments are divided, the foot inverted, and the bone twisted out.

Excision of Astragalus and Calcaneum.—Osteoplastic excision of the heel and ankle, Mikulicz (Fig. 317). An incision is carried from a point just in front of the tubercle of the scaphoid bone transversely across the sole of the foot to a point just behind the fifth metatarsal bone. From each end of this incision incisions are carried

upward and backward to points just above the two malleoli. These two last incisions are joined at their upper ends by a transverse incision passing around the back of the ankle. All of these cuts are carried down to the bone. The lateral ligaments of the ankle are then divided, and the calcaneum and astragalus dissected out. The malleoli with the articular surface of the tibia are then sawed off transversely, and likewise the posterior articular surfaces of the cuboid and scaphoid bones. The cut surfaces of the two tarsal bones are then brought up into apposition with the cut surfaces of the leg bones and sutured. As a result of this operation the weight of the body is borne upon the distal ends of the metatarsal bones, the toes being extended.

Excision of Metatarsal Bones.—The incisions for removal of these bones correspond to those employed in the hand. Every effort should be made to preserve the anterior extremity of the first metatarsal bone, as it constitutes the main anterior support of the arch of the foot. Likewise the importance of the great toe in walking should be remembered.

Excisions, Resections, and Erasions of the Larger Joints.—"Complete excision" of a joint means the removal of the articular ends of the bones which enter into the composition of the joint. "Partial excision" means the removal of the articular surfaces of one or more, but not all, of the principal bones entering into the joint. The term "resection" is applied to the removal of the entire thickness of a bone. Excisions of joints are done for destructive disease, infective disease (to stop its progress), old unreduced dislocations, ankylosis in faulty position, and to secure greater mobility in stiff or ankylosed joints. Erasion or arthrectomy means removal of the synovial membrane, and is practised in intractable infective synovitides and in the early stages of many of the diseases for which excision may be required. (See *Arthrectomy*, p. 746.) Excisions in children, removing the epiphysis, stop the normal growth of the limb. Fortunately, this operation for inflammatory disease has been much superseded in the last few years by more conservative measures, the old dependence upon drugs in the treatment of tuberculosis of bones and joints having been replaced by the restoration of the patient to normal hygienic conditions—pure air and simple, nourishing food. For adults, too, the operative treatment of chronic inflammatory diseases of joints has been minimized by the application of Bier's method of passive congestion. These advances in surgery, together with the improvements in the treatment of fractures and dislocations and the employment of arthrectomy, have made less frequent the systematic resections and excisions once practised so freely in the early days of the antiseptic era.

In excisions the main blood-vessels and nerves must carefully be guarded. When excision is done to secure ankylosis, the division of tendons and muscles is of little moment, but when mobility is hoped for, the conservation of these structures is imperative. The division of a tendon or muscle which is to be preserved should be made obliquely to facilitate its subsequent suturing. In sawing off the articular end

of a bone it is well to make a "conservative section"; that is, to remove as little as possible, and then use the curette or gouge to complete the eradication of the disease.

The total extirpation of joints without opening the synovial sac can be practised with success in the case of the knee-, ankle-, elbow-, and shoulder-joints, and the smaller joints of the hand and foot. The operation has little to recommend it, and presents the decided objection of removing the joint without an opportunity of previously inspecting it.

Arthrodesis (the artificial production of ankylosis) is practised chiefly upon the hip- and ankle-joints to improve the usefulness of the lower extremity in cases of paralytic relaxation and loss of control of the joint. Kofmann[22] has employed it in the treatment of paralytic hip-joint luxation. It is of special service in permanent paralysis of the leg muscles controlling the ankles. The operation consists in opening the joint by means of the incisions described under *Excision of Joints* (p. 769), thoroughly curetting the articular cartilages, applying pure liquid phenol to all of the articular and synovial surfaces, washing out with alcohol, cleansing with saline solution, closing the wounds without drainage, and immobilizing in the desired position. The immobilization should be complete and continue for six to eight weeks.

FIG. 318.—EXCISION OF THE SHOULDER-JOINT.
A, Anterior incision (Ollier); *B*, vertical incision (Langenbeck); *S*, curved incision for osteoplastic excision (Senn).

Excision of the Shoulder-joint.—This operation is usually a partial excision, as only the head of the humerus is removed. Removal of the head of the scapula is rarely required; when diseased, it can usually be treated with the gouge or curette.

Excision through an Anterior Incision (Ollier) (Fig. 318, *A*).—The patient lies upon his back close to the edge of the table with the shoulder somewhat raised. The arm is slightly abducted. The surgeon stands facing the patient, the first assistant stands above the shoulder, beside the patient's head, facing the operator. An incision 4 inches long commences at the outer side of the tip of the coracoid process and is carried downward and slightly outward, following the direction of the anterior margin of the deltoid muscle. This incision is carried down to the joint. The capsular ligament is opened just to the outer side of the tendon of the long head of the biceps, and the incision carried down to the humerus. The periosteum and capsular ligaments are then elevated from this line outward as far as possible while an assistant

rotates the arm inward. The periosteum, bearing the insertion of muscles into the greater tuberosity, is separated. The tendon of the biceps is then lifted out of the way, the arm rotated outward, and the periosteum and capsule elevated toward the axilla. The insertion of the subscapularis is elevated or dissected off with the periosteum. If the tuberosities are not diseased, the tendinous insertions may be more surely preserved by elevating a thin shell of bone with the periosteum by means of the chisel. The head of the humerus is then dislocated forward through the wound, the elevation of periosteum from the posterior surface completed, and the head of the bone sawed off. Any disease of the glenoid fossa is dealt with. Drainage, if necessary, is secured through a small opening made posteriorly.

If this subperiosteal operation cannot be done, the muscles are simply divided from the bone without preserving their attachments. If only the articular head is to be removed, the division can be made at the anatomic neck with the key-hole saw, wire saw, or chisel, without lifting the bone out of the wound. Early and persistent passive motion should be practised.

Excision by the Deltoid Flap.—The incision begins just below the tip of the acromion process, passes downward and curves outward across the arm about 2 inches below the top of the lesser tuberosity, then backward and upward to the top of the greater tuberosity. This operation has the great disadvantage that it divides the deltoid muscle, which, however, can be sutured. Its only advantage is that it gives a more free approach to the joint.

Excision through a Vertical Incision (Langenbeck) (Fig. 318, *B*). —The arm being rotated inward, the incision begins above at the anterior border of the acromion, just outside of the acromioclavicular joint, and passes downward about 4 inches in the line of the bicipital groove. The incision is carried down through the deltoid muscle to the tendon of the biceps. The sheath is split, the tendon retracted, and the joint opened through the sheath. The periosteum and capsule are elevated, first on the inner side and then on the outer side, the knife being used to separate these structures from the bone over the tuberosities. The operation is proceeded with as through the *anterior incision.* This incision has little to recommend it, as it destroys some of the nerve-fibers to the deltoid and approaches the joint through the thickness of the muscle.

Excision by a Transverse Incision (Nélaton).—An incision 3½ inches long is made ½ inch below the edge of the acromion and parallel to it, having its anterior end between the acromion and coracoid processes. The deltoid is divided through this incision and the joint freely exposed. The capsule is opened along the outer side of the biceps tendon and also transversely.

Excision by Division of the Acromion through a Posterior Incision (Fig. 314, *K*).—Kocher carries a curved incision from the acromioclavicular joint (which he opens) backward over the shoulder, along the acromion to its root, severing the trapezius, and from there downward

to the posterior fold of the axilla, ending about $1\frac{3}{4}$ inches above the lower border of the deltoid. The infraspinatus and supraspinatus muscles are separated from the acromion, and the process divided at its junction with the spinous process. The acromion with its attached deltoid is pressed over the head of the humerus. The joint is then opened along the line of the bicipital tendon. The tendon is retracted forward and the external rotators retracted backward. This exposes the head of the bone for such treatment as may be required. The acromion is sutured back in place.

Excision by a Curved Osteoplastic Incision (Senn) (Fig. 318, *S*).—An incision is begun at the coracoid process, curved gently downward and outward below the greater tuberosity, thence curving upward and backward the same distance, ends at the spine of the scapula. The semilunar flap thus formed is dissected up so as to expose well the acromion. The saw is applied, the acromion divided, and the fragment reflected downward with its deltoid connection. The capsule of the joint is opened and the disease dealt with. The operation is completed by suturing the acromion back in place with chromic gut sutures and closing the wound with or without drainage.

Excision of the Elbow-joint.—One of two results should be aimed for in this operation: the most useful possible movable joint, or ankylosis in flexion at an angle of 135°. While the former result should be striven for, usually ankylosis is preferable to a very loose joint. Complete excision is usually performed, for the reason that ankylosis is less apt to occur if all of the articular surfaces are removed. In typical excision the humerus is sawn through at the epicondyles, the ulna at the base of the coronoid process, and the radius at its neck. More than this must often be removed. Whenever possible all of the olecranon except its articular surface should be saved. When this can be done, the strong extensor attachment of the triceps is retained. It is also most important to retain the attachment of the brachialis anticus to the ulna and the bicipital attachment of the radius. The posterior aspect of the joint is superficial, the important vessels and nerves, excepting the ulnar nerve, all lying anteriorly. The ulnar nerve, which passes behind the internal condyle, lies along the inner side of the olecranon. Excision through the H-incision has been superseded by the method of the simple lateral incision on the radial side. After excision, if a movable joint is aimed for, the arm should be put up on a splint with the elbow flexed at an angle of 135°; that is, an angle midway between complete extension and right-angle flexion. The forearm should be midway between pronation and supination, the thumb directed upward. Passive motion should be begun in about a week after operation.

Excision by the Radial Incision (Ollier) (Fig. 319, *B*).—This is called the "bayonet incision." The patient lies upon the back close to the edge of the table. The upper arm should be held in a vertical position, the forearm slightly flexed and carried across the patient's chest. In operating on the right arm the surgeon should stand by the patient's loins, and in operating on the left arm he should stand a

little away from the patient's side. An incision is begun 2 inches above the upper end of the olecranon process on the outer side of the arm opposite the space between the supinator longus and the triceps; that is, about 1¼ inches above the external epicondyle. The incision is carried directly downward, parallel with the long axis of the humerus, to the epicondyle; thence downward and inward to the middle of the outer side of the olecranon; and thence again downward over the back of the olecranon and shaft for 1 or 2 inches. This is a skin incision, but over the ulna it goes down to the bone. The capsule of the joint is exposed by separating the triceps on the inner side and the supinator longus, extensor radialis longior, and anconeus on the outer side. The capsule is opened, the lower end of the humerus exposed, and the

FIG. 319.—EXCISION OF ELBOW-JOINT. *B*, Radial incision (Ollier); *L*, median incision (Langenbeck).

FIG. 320.—EXCISION OF ELBOW-JOINT. *N*, Right angular incision (Nélaton); *H*, *T*, long external and short internal incisions.

periosteum and capsular ligament divided about the outer edge of the articular surface and the muscular attachments elevated with the periosteal elevator. The periosteum of the ulna, carrying with it the tendon of the triceps, is next elevated, beginning at the outer edge of the articular surface. The external tuberosity of the humerus and the condyle are next denuded, the periosteum carrying with it the muscular and ligamentous attachments. The joint is then flexed, the lower end of the humerus dislocated into the wound, the separation of periosteum completed, and the lower end of the bone sawn off from one epicondyle to the other. The head of the radius is removed, and, after the completion of the denudation of the ulna, the upper end is sawn transversely through.

Excision by the Posterior Median Incision (Langenbeck) (Fig. 319, *L*).—The patient lies as in the above operation. A skin incision about 4 inches long, crossing the back of the joint, is made in the direction of the long axis of the forearm, beginning 2 inches below the top of the olecranon, following the posterior border of the ulna and passing upward across the center of the olecranon depression of the humerus. The knife bisects the triceps tendon and passes directly down to the bone. The joint is opened in the same line and the parts retracted. First the inner half of the triceps tendon is elevated with the periosteum from the olecranon. The periosteum is then divided at the inner side of the articular surface of the humerus and the inner condyle is cleared. If the elevator is kept close to the bone, the periosteum with the attached muscles may be lifted away from the bone and the ulnar nerve not injured. The internal lateral ligaments are also detached in the same way. The same process is applied to the outer side. When the outer condyle is reached strong retraction is necessary, and care must be given to keep close to the bone lest the posterior interosseous nerve be injured. The joint is now strongly flexed, the lower end of the humerus extruded through the wound, cleared of its attachments as high as is necessary, the articular surface grasped with lion-jaw forceps, and sawed through transversely just below the tips of the epicondyles. With the joint in the same position the upper ends of the ulna and radius are made to protrude through the wound, the soft parts are retracted, and the upper end of the ulna sawed off horizontally, carrying with it all of the articular surface and leaving as much of the coronoid process as possible. The upper end of the radius is sawed off at the same time.

Excision by the Right Angular Incision (Nélaton) (Fig. 320, *N*).—A longitudinal incision 3 inches long is made on the outer side of the joint, beginning on the outer side of the humerus about 1½ inches above the tip of the olecranon, and carried down behind the outer condyle to a point just posterior to the neck of the radius. From the lower end of this incision a second cut is carried inward at a right angle across the back of the ulna. The triangular flap, including the periosteum of the ulna, is dissected up. Kocher makes this incision in a J-curve. The external ligaments are divided and the head of the radius is removed. The denudation of the ulna is completed and the bone sawed across. The humerus is projected through the wound and treated as above described. This operation can only be recommended when the periosteum of the ulna is not divided transversely, but along the outer border of the olecranon, and elevated with the tendon of the triceps, as in the first operation described.

Excision by the Long External and Short Internal Incisions (Hueter) (Fig. 320, *H*, *T*).—A longitudinal incision, ½ inch long, is carried down upon the front of the internal epicondyle, and the muscles and internal lateral ligament are separated from the bone. An incision about 2½ or 3 inches long is then made behind the external epicondyle, ending below at the outer side at the head of the radius. The external lateral

ligament is divided and the joint is opened in this line. The head of the radius is removed. The lower end of the humerus is denuded, as described above, and removed, and likewise the upper end of the ulna.

The H *incision* (Moreau) was formerly used when the triceps tendon was cut through. This is now rarely done.

Partial excision is indicated when only a part of the articular surfaces requires to be removed. When only the lower end of the humerus is to be resected, the radial incision of Ollier or the external and internal incision of Hueter is indicated. The articular surfaces of the radius and ulna are best exposed by the median incision of von Langenbeck or the lower part of Ollier's radial incision.

Osteoplastic Excision (von Bruns).—For exposing the joint for the treatment of ankylosis, fungous arthritis, old or irreducible dislocations, and foreign bodies, transverse division of the olecranon process is often of much service. This operation is best done through the external incision of Ollier, which may be modified to suit the requirements of the case. The skin is retracted from the olecranon, and this process divided at its base and turned up. This exposure permits of a free exhibition of the joint. The end of the humerus or radius may be removed and the articular surfaces of the ulna dealt with. Conditions within the joint are rendered most accessible. If desirable, a transverse skin incision may be added, giving still more exposure. The operation is completed by suturing the olecranon back in place with chromicized catgut or silver wire, just as is done for fracture.

Excision of the Elbow for Ankylosis.—This operation is indicated to secure a better position in cases of faulty bony ankylosis. The bone can best be exposed by the long posterior incision. The periosteum should be elevated and the ulna divided. The periosteum and capsule are detached, and the lower ends of the humerus and, if necessary, the radius and ulna sawed off. This operation may be carried out through the incision of Ollier by the osteoplastic method. The operation may be still more simplified by exposing the joint through a posterior H incision, dividing the olecranon, and then with knife and chisel dividing the ankylosing structures in the joint. After operation the elbow should be put up at an angle of 135°, and, if a movable joint is to be hoped for, passive motion begun early.

Excision of the Wrist.—This operation is done for disease of the carpal bones, and, as the disease commonly involves the lower end of the radius and the upper ends of the metacarpal bones, excision of the articular surfaces also becomes a part of the operation. The wrist bones are best approached in the triangular space between the extensor tendons of the thumb and index-finger. At this place are no important structures, and free access to the wrist is secured. As in other parts, it should be borne in mind that a typical operation should not be aimed at. The surgeon should preserve the bones which are free from disease. This is particularly important in the case of the trapezium which supports the thumb. The operation of complete excision is best performed by an outer and inner dorsal incision com-

bined. After any of these operations the hand and forearm should be put upon a splint and passive motion should be applied to the fingers early. The splint must be worn for two months or more until the parts have become adjusted.

Excision by Two Dorsal Incisions (Ollier) (Fig. 321, *A*, *B*).—The patient's hand, dorsum upward, is placed upon a small table at the side of the operating table. The radial incision begins over the lower border of the lower extremity of the radius, midway between the two styloid processes, and is carried obliquely downward to the outer side of the middle of the second metacarpal bone. For convenience in reflecting the soft parts the upper end of this incision may be extended inward 1½ inches further. The tendon of the extensor indicis is retracted outward and the metacarpal bones exposed. Care should be taken not to divide the dorsal branch of the radial nerve. The wrist-joint is opened and the posterior annular ligament divided. The ulnar incision is next made. It begins at a point 1½ inches above the tip of the styloid process of the ulna and passes downward to the base of the fifth metacarpal bone. It passes along the outer side of the tendon of the extensor carpi ulnaris. This incision is carried down to the bone, exposing the ulna, the cuneiform, and the unciform. Care should be taken to avoid cutting the dorsal branch of the ulnar nerve to the little finger. The removal of the carpus is accomplished by stripping the bones of their ligaments and periosteum, and lifting them out with the curette or forceps. The bones are removed through whichever incision renders them most accessible.

FIG. 321.—EXCISION OF THE WRIST-JOINT.

A, *B*. Two dorsal incisions (Ollier); *C*, single dorsal incision (Boeckel); *D*, *E*, bilateral incisions (Lister); *B*, *D*, internal and external dorsal incisions (combination of incisions of Ollier and Lister).

The removal of the ends of the radius and ulna is accomplished by making them protrude through the wound, stripping back the periosteum, and sawing off the diseased articular surfaces. If the disease is not extensive, it may be removed by the gouge or curette. The removal of the proximal ends of the metacarpal bones, if necessary, is accomplished in the same manner. Drainage-tubes are inserted and the hand put upon a splint.

Excision by a Single Dorsal Incision (Boeckel, Langenbeck) (Fig. 321, *C*).—This incision is placed in the interval between the extensor indicis and the extensor secundi internodii pollicis; following closely the outer border of the former of these tendons. It is about 4 inches long, and begins 1½ inches above the joint line over the lower end of the radius, and ends over the middle of the second metacarpal bone. The dorsal structures are dissected up by overextending the wrist, thus relaxing the extensor tendons. Through this incision a subperiosteal operation is done, but not so easily as with the two lateral dorsal incisions.

Excision Through Bilateral Incisions (Lister) (Fig. 321, *D*, *E*).—The radial incision begins above at the middle of the lower extremity of the radius at a level with the base of the styloid process. It passes downward and outward, parallel with the tendon of the extensor longus pollicis, to the inner side of the first carpometacarpal articulation, and thence directly downward along the outer side of the second metacarpal bone for half the length of the bone. This incision is about 4 inches long, and placed so as to avoid the radial artery. It should pass down to the bone and sever the tendons of the extensor carpi radialis longior and brevior at their insertions, but not the tendons of the thumb. The soft structures on the ulnar side of the incision are then dissected up, the wrist being strongly extended. The long and short extensors of the wrist are divided. The trapezium is separated and left for the last, if its removal is necessary.

The ulnar incision is begun two inches above the lower end of the ulna on its anterior aspect, and passes downward between the bone and the tendon of the flexor carpi ulnaris as far as the middle of the palmar side of the fifth metacarpal bone. The inner side of the wound is retracted, and the tendon of the extensor carpi ulnaris cut at its insertion. The wrist is then strongly extended and the soft structures dissected away from the bones. The posterior ligaments are divided, and the joint opened. The connection of the tendons with the radius is left undisturbed. The carpal bones are easily removed through these incisions, and the ends of the radius and ulna and metacarpal bones given the necessary attention. The trapezium is examined last, care being taken to avoid injury to the tendon of the flexor carpi radialis and to the radial artery. The non-articular parts of the pisiform and unciform bone should be left, if sound.

Excision of the Hip-joint.—This operation is done usually for disease of the head of the femur, and is, therefore, an incomplete excision. When the joint is exposed, any other foci of disease are to be dealt with as the case may require. The acetabulum may be diseased and necrotic pieces of bone required to be lifted out or carious foci gouged or curetted. The operation is simple, and the only condition which presents a difficulty is the presence of the heavy muscles by which the joint is surrounded. The joint is best exposed by the external incision. Extension for a few days in bed or with the Thomas splint should follow the operation.

Excision of the Hip-joint by a Straight External Incision (Langenbeck) (Fig. 322, *A*).—The patient lies upon the sound side; the diseased thigh is flexed at an angle of 45°, and rotated slightly outward. A straight incision 4½ inches long is made in the direction of the long axis of the femur. It should lie a little behind the middle of the great trochanter. Two-thirds of the length of the incision should be above the trochanter and one-third of the incision should lie on the femur. The upper end of the incision will thus lie about opposite the great sciatic notch. The knife above the trochanter is carried down to the muscle, the fibers of which are separated down to the joint and, below,

FIG. 322.—EXCISION OF THE HIP-JOINT.
A, Straight incision (Langenbeck); *B*, curved incision (Ollier); *C*, curved incision (Sayre); *D*, curved incision (White).

the incision is made down to the bone. The muscle is retracted and the capsule of the joint opened in the direction with the line of incision. The capsular ligament is also divided transversely close to the acetabulum. The muscles inserted into the great trochanter are divided at the insertion. If the ligamentum teres has not been destroyed by disease, it must be divided. The thigh is now rotated inward and the head of the bone is dislocated backward and thrust out of the wound. The soft parts are protected by retractors, and the diseased upper end of the bone sawed off. Free access to the acetabulum is thus secured. Further diseased bone is gouged or curetted, sinuses followed up, and diseased synovial membrane removed. A drainage-tube may be left.

in the wound for a few days. The joint should be immobilized by a Thomas hip splint, a long side splint, or a light plaster-of-Paris case.

Excision of the Hip by a Curved Incision.—Ollier used a curved incision (Fig. 322, *B*), beginning 3 inches below the crest of the ilium and the same distance behind the anterior superior spine, passing downward to the great trochanter, and thence down the shaft of the femur, uncovering the bone. Its length should be about 5 inches. The superficial fascia being retracted, the gluteus maximus will be found posterior to the incision. The fibers of the gluteus medius and the gluteus minimus are separated in the line of the incision, and the capsule of the joint exposed without dividing the muscle.

Sayre made a still more curved incision (Fig. 322, *C*), beginning midway between the anterior superior spine of the ilium and the top of the great trochanter, passing in a gentle curve down across the trochanter, midway between its middle and posterior border, and thence curving forward and downward. This incision ends just above the level of the lesser trochanter, and is about 6 inches long. Throughout its whole length the knife is carried down to the bone and through the periosteum. The soft parts are retracted, the periosteum is divided transversely just above the level of the lesser trochanter, the division being carried around the bone as far as possible. The two flaps of periosteum are stripped up, beginning at the junction of the two incisions. At the digital fossa the muscular insertions are divided and the separation of the periosteum continued as far as possible without tearing it. The thigh is then adducted and the head of the femur raised out of the acetabulum. The periosteum can then be separated around the inner aspect of the bone. The femur is then sawed through just above the lesser trochanter. White's incision (Fig. 322, *D*) for exposure of the hip-joint begins at the same point above as Sayre's, but makes a wider curve and passes down behind the great trochanter.

Excision of the Hip by an Anterior Incision (Baker).—The patient lies supine, the surgeon standing by the right side of the patient. The incision begins ½ inch below the anterior superior spine of the ilium and passes downward and slightly inward for 3 inches. The opening through the muscles is made between the tensor vaginæ femoris and the glutei on the outer side, and the sartorius and rectus on the inner side. The joint is exposed and the neck of the femur sawn through in the direction of the external incision.

Excision of the Knee-joint.—As the knee-joint depends upon its ligaments for rigidity, a complete resection should be followed by bony ankylosis in order to give the best result. If it becomes necessary to remove the upper end of the tibia, a slice of the articular surface of the femur should be removed, even though it is not diseased, for the purpose of securing the flat bony apposition essential for good bony ankylosis. In children it is imperative that the epiphyseal line (especially the one at the lower end of the femur, as the greatest growth of the entire skeleton takes place here) be not disturbed unless the extent of the disease makes it absolutely necessary.

(See Diseases of Bones, Vol. II., p. 17.) The epiphyseal line of the femur is horizontal with the tubercle of the adductor magnus. If the whole articular surface is taken away by a horizontal cut, the whole epiphysis will have been removed. The epiphyseal line of the tibia is horizontal with the bottom of the tuberosities behind. The facet for the fibula is on the epiphysis. The line slopes downward and forward, so that the tubercle of the tibia is on the epiphysis. The line lies below the joint capsule. In 72 per cent. of cases subjected to excision between the ages of three and fourteen years, deviation of the knee takes place as a result of unequal growth of the lower end of the femur.[23] After fourteen no deviation seems to occur. This is apparently due to the fact that the quadriceps muscle becomes weakened to a much greater degree than the flexors of the knee, the latter continuing to functionate because of their attachment to the pelvis. Tenotomy of the hamstrings in children under eight years of age should be done after excision of the knee-joint.

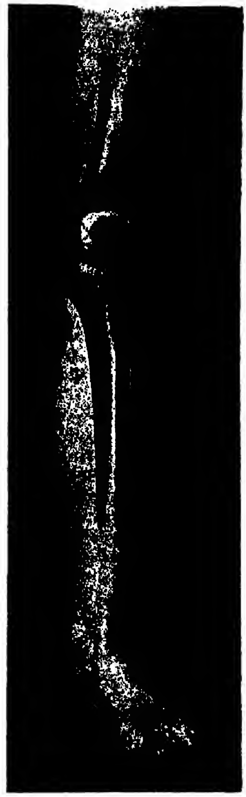


FIG. 323.—EXCISION OF THE KNEE-JOINT.

Operation (Fig. 323).—The knee is slightly flexed. The incision begins on the side of the limb opposite the posterior and upper part of the condyle, curves downward and across the front of the joint, midway between the patella and the tuberosity of the tibia, and ends at a corresponding point on the opposite side. This incision divides the skin and fascia down to the ligaments. The knee is now more strongly flexed, and the patellar ligament is divided and the joint opened. The joint is now strongly flexed, the patella turned up, and the lateral and crucial ligaments divided. The posterior ligaments are not disturbed.

The articular end of the femur is cleared of soft tissue, grasped with the lion-jaw forceps, and sawed through, care being taken to protect the popliteal vessels from injury. The same thickness of each condyle should be removed, to obviate the tendency to knock-knee or bow-leg. The bone should be divided in a line parallel to the plane of articulation. The foot should rest squarely upon the table, the leg be held in a perpendicular position, and in this position a thin slice of the upper end of the tibia sawed off in a line parallel with the articular surface. This is best done with the flat saw. Any diseased foci not removed by these cuts should be removed with the gouge or the curette. Oblique lines of division may be employed if thereby a larger amount of healthy bone can be preserved. This is always possible when the disease occupies but one side of the bone or opposite sides of the two opposing bones.

Often in such cases an osteoplastic operation in the form of a step may be done to advantage, thus saving in the length of the limb. The two bony surfaces, when apposed, should bring the leg into its natural line. A very slight degree of flexion is advantageous.

The patella, if not diseased, should be left. If it is diseased, the gouge or the curette may be used to scrape away the affected portions. If only the articular surface is affected, the bone may be steadied with the lion-jawed forceps, and the articular surface sawn off, leaving the anterior part of the bone. The diseased synovial membrane should be removed, and sinuses and pockets cleaned out with scissors and curette. The reflection beneath the quadriceps extensors should not be neglected. Any diseased spots in the remaining bone should be curetted.

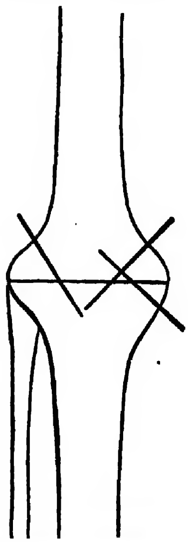


FIG. 324.—BONES HELD BY NAILS AFTER RESECTION OF THE KNEE-JOINT.

The bones should be held together by a few strong sutures of chromicized gut passed through the lateral ligaments, which should be trimmed to give the best line for suturing, or bone nails may be employed (Fig. 324). The divided patellar ligament should be sutured. The necessity for drainage will depend upon the conditions present. The leg is put upon an immobilizing splint, and maintained immobilized until solid bony union has been secured. The use of the Esmarch bandage in this operation permits the operation to be done more rapidly and, as no vessels of consequence are divided, the wound may be closed and the pressure of the dressings depended upon to prevent hemorrhage. A small drainage-tube on either side of the knee for twenty-four or forty-eight hours is desirable. There is usually much pain after the operation. This may be ameliorated and bloody oozing diminished by elevating the foot.

Many modifications of this operation are in use. Ollier employed a lateral incision along the outer side of the patella. Hahn carried the transverse incision above the patella, convexity upward. Volkmann's incision passes directly across the front of the patella, which is sawed through transversely. Kocher carries a curved incision from above the outer condyle downward and inward to the inner aspect of the tibia below the tuberosity, and chisels off the tubercle bearing the patellar ligament.

Walkowitch[24] of Kiew has devised an operation for excision of the knee-joint without opening the joint. A similar operation is described by Flint[25] of New York. This operation consists in removing the unopened capsule along with the two bone ends, and is performed through the large U-shaped incision, the synovial sac being dissected down from beneath the quadriceps muscle, and the bone ends sawed off beyond the attachments of the synovial membrane, so that they come away with the unopened joint capsule.

Arthrectomy or Erasion of the Knee-joint.—Volkmann's method of performing "arthrectomia synovialis" has not been materially modified. The joint is opened by the U incision employed for resection, or the patella may be sawn through. The flap is turned up and the diseased tissue in the bursa back of the quadriceps is removed in one mass. The capsule and synovial membrane attached to the tibia are removed in the same manner. The dissecting out of the synovial membrane should be continued until all diseased tissue down to bone and muscle is removed. The crucial ligaments may be divided, if necessary, to reach the back of the joint. The posterior ligament should be preserved. After dissecting out all disease of the soft parts diseased foci in the bone should be sought for and treated with the gouge or the sharp curette. The ligaments should be sutured back in place. A small tube for drainage on either side should be arranged so that it can be withdrawn at the end of forty-eight hours. The knee should be put up in an immobilizing splint with the slightest degree of flexion. While Esmarch's constriction is generally advised against, I believe that here, as in excision, it enables the surgeon to work more rapidly and more easily to discover diseased tissue, and it is, therefore, to be recommended.

Senn advocates a curved incision, passing above the patella with the convexity upward. The patella is sawed through transversely, and the upper portion of the synovial sac is exposed by two lateral incisions. An operation which I can recommend consists in the ordinary curved incision, convexity downward, dividing the patellar ligament, and to this I add a median incision, bisecting this flap and the patella and freely laying open the pouch beneath the extensor muscle. This gives free access, obviates transverse division of the patella, adds no hemorrhage, and simply splits the fibers of the muscle. No attempt to secure mobility after arthrectomy of the knee for tuberculosis should be made; the best result is with ankylosis.

Excision of the Ankle-joint.—This operation was formerly done for tuberculosis and injury. It is no longer resorted to as a typical operation in the latter condition; and in tuberculosis it has given results which have proved so unsatisfactory that it is now but little used. Quite invariably tuberculosis of the ankle-joint is associated with disease of the tarsal bones, and excision of the joint has required subsequent operations to effect a cure. Amputation, on the whole, giving the best assurance of a cure, and, with a good prosthetic apparatus, as useful a limb, has been resorted to more and more in advanced cases.

Excision by an External Curved Incision (Lauenstein) (Fig. 325, *L*).—An incision begins just posterior to the fibula, 2 inches above the malleolus, passes down the posterior border of the bone, curves forward beneath the malleolus, and terminates on the outer aspect of the dorsum of the foot at the astragaloscaphoid articulation. The fibula is exposed and the periosteum divided and reflected, carrying with it the two peronei tendons. The fibular attachment of the external lateral ligament is divided, and the lower inch of the fibula cut off. By retracting the

skin-flap and tendons the anterior surface of the lower end of the tibia is brought into view. The foot is now completely inverted, exposing freely the articular surfaces of the joint. The necessary resections can now be made, the foot replaced, and the parts sutured.

Excision of the Ankle by Bilateral Incisions (Figs. 315, *B*; 316, *B*).—A vertical incision three inches long is made along the anterior part of the fibula, ending just below the tip of the malleolus. It is joined at its lower extremity by an incision which curves around beneath the malleolus and ascends for one inch behind the fibula. Through this incision the periosteum and the tendons are elevated from the fibula, the lateral ligaments divided, and the lower inch of the bone cut off. The outer aspect of the tibia in front and behind is reached through this wound and denuded of periosteum. An inner longitudinal incision is carried for three inches along the inner surface of the tibia, ending at the

FIG. 325.—*A*, Excision of calcaneum (Ollier); *B*, excision of astragalus (Ollier); *L*, Excision of ankle-joint (Lauenstein).

tip of the malleolus. This is joined at its lower end by a short incision at right angles. The periosteum of the tibia is incised longitudinally and elevated anteriorly and posteriorly until the denudation meets that which was started from the outer side. The internal lateral ligament is divided, care being taken to protect the structures passing beneath the malleolus. The lower end of the tibia is then divided with the small saw and removed. The articular surface of the astragalus is sawed off through the outer wound, or, if necessary, the whole bone may be removed.

Excision of the Ankle by the Transverse External Incision (Kocher).—The incision is begun anteriorly, ½ inch below the center of the ankle-joint, passes outward and backward below the malleolus, and thence curves upward to the tendo Achillis. The common extensor tendon is avoided, also the musculocutaneous and short saphenous nerves. The

foot is strongly inverted, the external ligaments divided, the tendons retracted, and the operation completed as above.

Excision of the First Metatarsophalangeal Joint.—This operation is best done through an incision on the dorsum of the foot, placed just internal to the tendon of the great toe. The scar of this wound comes between the first and second metatarsal bones, and is least exposed to irritation.

ARTHROTOMY.

Arthrotomy, or incision into a joint, is done for purposes of drainage of septic joints, for the liberation of fluids and blood, for the removal of loose cartilages and floating bodies, for the removal of foreign bodies, and for the purpose of introducing medication into a joint. For purposes of drainage the opening, when possible, should be made at the lowest part of the joint. In operating for the purpose of securing drainage the general principles of surgery, demanding opening at the most dependent part, must often be modified by the anatomic peculiarities of the joint. The knee-joint, particularly, has suffered from this, it being customary to open it for drainage laterally, leaving the posterior half of the joint sac undrained. It is not difficult to reach the joint through an opening made at its most posterior part. Such an opening offers drainage at the bottom of the joint-sac as the patient lies recumbent; and in virulent infections is much to be preferred to the lateral opening. Posterior drainage is best secured through incision directly over the posterior aspect of the condyles. This opens into the pouches of synovial membrane lying in front of the heads of the gastrocnemius. Care should be taken not to injure the long saphenous vein or the external peroneal nerve.

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CHAPTER LXXV.

AMPUTATIONS.

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THE METHODS OF AMPUTATION.

The Evolution of Amputation Methods.—The methods of amputation have undergone a slow process of evolution, which may be briefly stated in the following tabular form (modified from Kocher):

Circular Incision.—This is the fundamental type of amputation. Of this, there are two varieties, and from it all other methods of amputation may be derived: (*a*) Transverse circular incision (Fig. 326, A); (*b*) oblique circular incision (Fig. 326, B).

Racket Incision.—This is formed by the addition of a longitudinal incision to the circular incision. (*a*) If the longitudinal incision be

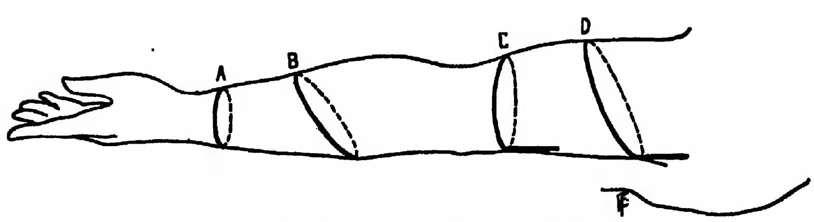


Fig. 326.—The Evolution of Amputation Methods.
A, Transverse circular incision; B, oblique circular incision; C, transverse racket incision; D, oblique racket incision. (Modified from Kocher.)

added to the transverse circular incision, the transverse racket incision results (Fig. 326, C); (*b*) if the longitudinal incision be added to the oblique circular incision, the oblique racket incision results (Fig. 326, D).

Note.—The corners of the racket incision are now generally rounded off, as in the oval method, the only practical difference between the two, as now usually employed, being that the queue is made longer in the racket method.

Oval Incision.—This is formed by the shortening of the queue and the rounding-off of the angles of the racket incision. (*a*) If the angles of the transverse racket incision be rounded, the transverse oval

incision results (Fig. 327, A); (*b*) if the angles of the oblique racket incision be rounded off, the oblique oval incision results (Fig. 327, B).

Rectangular flaps are formed by adding two longitudinal incisions to the circular incision. (*a*) If the two longitudinal incisions be added to the circular incision, equal rectangular flaps result (Fig. 327, C); (*b*) if they be added to the oblique circular incision, unequal rectangular flaps result (Fig. 327, D).

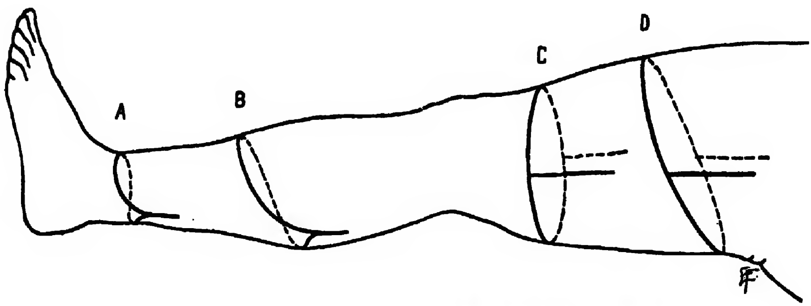


FIG. 327.—THE EVOLUTION OF AMPUTATION METHODS.
A, Transverse oval incision; B, oblique oval incision; C, equal rectangular flaps; D, unequal rectangular flaps. (Modified from Kocher.)

Rounded flaps are formed by rounding the angles of the rectangular flaps. (*a*) If the angles of equal rectangular flaps be rounded, equal rounded flaps result (Fig. 328, A); (*b*) if the angles of unequal rectangular flaps be rounded, unequal rounded flaps result (Fig. 328, B).

Elliptical Method.—The position of this method, in the process of evolution, will be described further on.

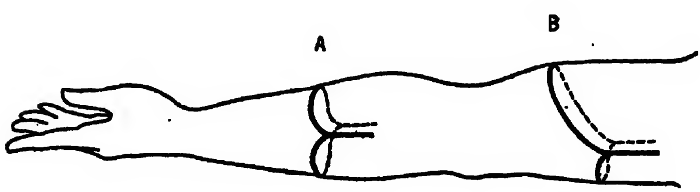


FIG. 328.—THE EVOLUTION OF AMPUTATION METHODS.
A, Equal rounded flaps; B, unequal rounded flaps. (Modified from Kocher.)

Summary of Amputation Methods.—Fundamental Types.—Circular method; flap method.

Modern Types.—(*a*) Circular and its modifications; (*b*) flap and its modifications; (*c*) irregular methods of amputation.

As to Nature of Covering of Stump.—All methods of amputation are either—(*a*) Coverings of skin—that is, skin and fascia alone cover the divided muscles and bone, as in the cuff method of the circular

amputation, and in the simple skin-flap in the flap method of amputation; or (*b*) coverings of skin and muscle—where skin, fascia, and muscles, combined and unseparated, including the periosteum, cover the end of the bone, as in the ordinary (infundibuliform) circular amputation, and in flaps of skin and muscle in the flap method of amputation.

Circular Methods of Amputating.—(*a*) Ordinary circular method; (*b*) cuff method of circular amputation; (*c*) modified circular method of amputation (mixed method); (*d*) oval (or lanceolate) method; (*e*) racket method.

Ordinary Circular Amputation.—Technic.—Stand to outer side of right and inner side of the left limbs, so as to grasp the limb between trunk and amputation-site. Determine the saw-line. Fix the skin-incision at a level below the saw-line equal to ½ of 1½ times the diameter of the limb (or three-fourths of that diameter) at the saw-line (that is, at 11.5 cm., or 4½ inches, below the saw-line, if the diameter of the limb at the saw-line be 15.3 cm., or 6 inches). Grasp the limb just above the line of the skin-incision with the left hand and retract the skin upward, aided, if the limb be large, by an assistant. With a long knife, make a circular incision, at the skin-incision line, through skin and superficial fascia, entirely around the limb. Free the skin with its superficial fascia from the muscles with their deep fascia, aiding the separation in the interfascial line by touches with a scalpel, where necessary. Retract the skin and fascia evenly around the circumference of the limb. Divide the more superficial layer of muscles circularly on a level with the retracted skin. Retract this more superficial layer of muscles. Divide the remaining deeper muscles circularly on a level with the retracted outer layer of muscles, and planning to come down upon the bone, or bones, far enough below the saw-line to allow of making a musculoperiosteal covering for the bone or bones. Retract the deeper muscles thus cut. Divide with a stout knife the periosteum circularly around the bone, or bones, at a distance below the saw-line equal to a good one-half diameter of the bone at the saw-line. Push up the periosteum from the bone with periosteal elevator, keeping the muscles adherent to the periosteum. Apply linen (or other) retractors to the soft parts and draw them above the saw-line. Saw the bone or bones. If splintering occur, grasp the spicula with forceps and remove with finer saw. Allow the soft parts to drop over the end of bone, or bones, the sawed ends of which will form the apex of a funnel, the bone being covered by periosteum, periosteum by muscle, and muscle by fascia and skin. Tie the vessels, cut the nerves and tendons short, and remove any tags of connective tissue or skin. Suture the musculoperiosteal covering over the end of bone or bones. Quilt the muscles together in one or two layers. Suture the skin and fascia anteroposteriorly and apply the dressing and supporting splint.

The **resulting stump** is evenly covered on all sides by muscle and skin, the bone being particularly well protected and on a higher

level above the surface of the stump than in any other form of amputation. The scar is terminal, anteroposterior, if the wound be sutured from before backward, lateral, if sutured from side to side.

Indications.—In limbs more or less evenly surrounded by muscles: lower part of forearm (sometimes), arm, and thigh.

Comment.—(1) Owing to unequal retraction of the skin in some localities (as the antero-internal aspect of the arm and thigh) the circular incision may have to be planned obliquely and only become circular after the incision, and may also have to be planned lower. (2) A pure ordinary circular (infundibuliform) amputation is impossible in a limb of rapidly increasing girth, as it is impossible to retract the soft parts. A single lateral vertical incision through skin and fascia, or double lateral incisions, may become necessary in order to free the parts, when it ceases to be a typical infundibuliform amputation.

Cuff Method of Circular Amputation.—Technic.—The steps of the operation are similar to those of the ordinary circular amputation up to the completion of the circular incision through the skin and superficial fascia. The skin and subcutaneous tissue are then turned back upon themselves as a cuff, the freeing being done by means of the fingers of the left hand, aided by touches of a scalpel, until evenly retracted all around. On a level with the retracted cuff the muscles are circularly divided down to the bone, the site at which this division takes place being such as will allow of ample and easy covering of the transversely divided muscle by the skin and fascia—an average calculation being that about one-third of the total distance from saw-line to line of skin-incision should be given to skin and fascia alone. The subsequent steps of the operation, including the musculoperiosteal covering for the bone, being the same as for the ordinary, or infundibuliform, circular amputation.

The **resulting stump** is apt to be more or less irregular in contour, and not so well padded, owing to the nature of the parts used for covering. The scar lies as in the ordinary circular amputation.

Indications.—It is most frequently used where the soft coverings are more tendinous than muscular: *e. g.*, wrist, lower part of forearm, ankle, and lower part of leg (in thin subjects).

Comment.—(1) and (2) The same comments made under (1) and (2) of the last operation apply equally here. (3) Owing to the greater proportion of skin in this covering and the division of muscles in one layer, as well as the number of tendons present in the sites where this method is generally used, the covering of the bones is not so satisfactory as in the ordinary circular method.

Modified Circular Amputation.—General Description.—Two equal flaps, composed of skin and fascia, of varying length, and having bases equal to one-half of the circumference of the limb at their upper ends, are cut and dissected up a short distance, followed by a circular sweep of the knife through the retracted superficial muscles, and by a second circular sweep at a higher level, through the retracted

deeper muscles, and completion of the operation as in the ordinary circular amputation.

Technic.—Having fixed upon the saw-line and having marked a point below the saw-line equal to $\frac{1}{2}$ of $1\frac{1}{2}$ diameters of the limb at the saw-line (that is, three-fourths of the diameter at the saw-line), two equal flaps of skin and fascia (of this length) are planned. These flaps have bases equal to one-half the circumference of the limb at the level of their upper limit, and their length will be equal to one-third or one-half of the total distance between the saw-line and the lowest limit of skin covering (generally one-third in slender, ill-formed limbs, and often one-half in large, tapering limbs). The flaps are usually lateral ones, but may be anterior or posterior. Retracting the skin with the left hand, begin the incision at one midlateral aspect of the limb, at a level above the lowest limit of the skin-incision, equal to one-third or one-half, as the case may be, of the distance between the saw-line and the lowest limit of the skin-incision, pass vertically downward through skin and fascia, until nearly at the level of the lowest skin-incision, thence round forward into the line of lowest skin-incision, in a bluntly rounding manner, and complete the opposite end of the same flap in the same manner. Then make the opposite flap in the same way as the first one, corresponding in shape and size. Dissect these flaps of skin and fascia back to just beyond their bases. While the flaps, and the muscles also, are retracted, divide the more superficial muscle circularly; retract these, and divide the deeper muscles similarly, making the usual provision for the musculoperiosteal covering. The operation is completed as in the ordinary circular amputation, the skin and fascial flaps being sewed over the quilted muscles, the bone being at the apex of a funnel which is somewhat shallower than in the infundibuliform variety of circular amputation, owing to the muscles having been divided at a higher level.

Resulting Stump.—While not covering the end of the bone with quite as thick a padding of soft parts, its general features are the same as those following the ordinary circular method. The main part of the scar is terminal, but its ends are apt to be partly lateral.

Indications.—This is the form of circular amputation most frequently used, and is adapted to a greater number of sites than the ordinary circular or the cuff modification of the ordinary method.

Comment.—(1) The skin-flaps may be cut of unequal lengths. (2) The muscles may be divided at one level. (3) This form of circular amputation has largely replaced either of the other forms.

Oval Method of Amputation.—Technic.—This amputation being generally used in disarticulations, the upper or pointed end of the oval usually begins just above a joint-line and upon its outer or anterior aspect, the limbs of the oval parting at an angle sufficient to include the head of the distal bone, and sweeping thence in a curve down the lateral aspects of the limb, passing, finally, transversely toward each other, to meet upon the inner or under surface of the distal limb and at a distance beneath the line of articulation calculated

to furnish sufficient covering for the head of the proximal one of the bones making up the joint. Having completed the incision through skin and fascia, one of two courses may then be adopted: (*a*) The incision may then be deepened throughout direct to the bone, by cutting from without; the deep incision, from the point where the arms or limbs of the oval begin to diverge, following the line of the retracted skin. This is the general method in all of the smaller disarticulations and in most of the larger. (*b*) Or the joint may be opened by the more vertical part of the incision, and, after disarticulation, the muscles may be cut from within outward, on a line with the retracted skin. Having tied the vessels and cut the nerves and tendons short, the wound is sutured in its long axis.

Resulting Stump.—The end of the bone is very fully covered, except where the head or articular end of the proximal bone is disproportionately large. The scar is terminolateral.

Indications.—A form of amputation generally used for disarticulating a limb from the trunk, or a smaller limb from a larger limb. The method admits of first opening the joint for investigation before finally deciding upon amputation, and it also admits of securing the vessels before removing the limb.

Comment.—The suture-line may run anteroposteriorly in one straight line, or the free, lower convex border of the flap may be turned over and sutured to the upper angular concavity of the wound.

Racket Method of Amputation.—Technic.—Practically similar to the oval amputation, except that the queue of the racket begins considerably farther back over the head of the proximal bone forming the joint, and along this single straight line the knife travels some distance before the arms of the racket begin to diverge. After the beginning of the divergence of the limbs of the racket the operation is completed as in the oval operation.

Resulting Stump.—More satisfactory covering is secured by the racket than by the oval method of amputating. The scar is terminolateral.

Indications.—Disarticulations of the shoulder- and hip-joints and of the digits from the hand and foot (especially, in the latter instances, where a metatarsal or metacarpal bone is removed with the digit). As in the oval method, but to a much greater extent, the racket method admits of a preliminary examination of the joint through the vertical portion of the incision before deciding upon amputation. The vessels may also be secured before entirely separating the limb. The muscles in the stump are better preserved.

Comment.—(1) The queue of the racket should be placed, if possible, over an intermuscular septum and be deepened in the septum. (2) Amputation by a T-shaped incision is, practically, a form of racket incision. (3) The suture line may run anteroposteriorly (or from the outer to the inner aspect of the part), which is to be preferred. Or the upper portion of the queue may be sutured in this manner and

the lower convex portion of the flap brought up and sutured to the angular concavity formed by the divergence of the lateral limbs of the racket.

Flap Methods of Amputating.—(*a*) Single flap of skin and muscles. (*b*) Single flap of skin. (*c*) Equal flaps of skin and muscles. (*d*) Equal flaps of skin. (*e*) Unequal flaps of skin and muscles. (*f*) Unequal flaps of skin. (*g*) Elliptical method. (*h*) Unequal rectangular flaps of skin and muscle.

Amputation by Single Flap of Skin and Muscles.—Technic.—Having fixed upon the saw-line (or line of disarticulation), a point is determined upon below this line, and on that aspect of the limb which is to furnish the flap, which will represent a distance below the saw-line equivalent to 1½ diameters of the limb at the saw-line. A flap is then marked out with a base equal in width to a half-circumference of the limb at the saw-line, and a length equal to 1½ diameters of the limb at that line. Grasping the limb as in the ordinary circular amputation, the knife is entered at the far upper end of the base of the flap, at a right angle to the skin, and passes vertically down the mid-axis of the limb to near the lower limit of the flap, where it forms a squarely or bluntly rounded corner to the flap, thence passes transversely along the lower limit of the flap, and completes the opposite limb of the flap symmetrically with the first limb. This incision passes through skin and fascia. When this integumentary flap has retracted, the muscles are cut obliquely on a line with its retracted edges, so directing the knife as bluntly to bevel the muscular portion as the knife cuts its way from without inward and upward. This incision passes obliquely through all the muscles and is planned to come down upon the bone at a distance beneath the saw-line equivalent to a good diameter of the bone at the saw-line, thus providing for a musculoperiosteal covering. The knife is then carried through the periosteum so as to form a musculoperiosteal flap with a base of half the bone at the saw-line and a length of once the diameter. The musculoperiosteal covering is then detached back to the saw-line. Divide the hitherto undisturbed soft parts on the opposite side of the limb by a circular sweep of the knife, passing through the skin and fascia of the half-circumference a little below the level of the base of the single flap, and through the muscles on a level with the base of that flap, including the periosteum. Retract all the soft parts on the proximal side of the saw-line and divide the bone. Suture the musculoperiosteal flap over the bone, the free edge of the periosteal flap being sutured to the half-circumference of the opposite aspect of the periosteum. Quilt the lateral and terminal aspects of the cut muscles in the flap with the transversely cut ends of the muscles on the opposite side of the limb. Suture the terminal and lateral aspects of the skin of the flap to the transversely divided skin of the opposite side.

Resulting Stump.—The stump is at first well covered with muscle, and, when this atrophies, by the replacing fibrous tissue. The scar is lateral.

Indications.—Cases of injury so destroying the soft parts as to leave those of but one aspect available. Also in such cases as Farabeuf's amputation of the upper third of the leg by a single external flap of skin and muscles, or Dubreuil's disarticulation at the wrist by a single external flap of skin and muscles.

Comment.—(1) In all flaps skin must be longer than muscle. (2) There is sometimes an excess of muscle in a flap, part of which should be removed in the process of beveling, but a fully muscled flap is generally desirable. (3) A flap of skin and muscle is more apt to live and makes a better covering than one of skin alone. (4) While the muscular tissue as such may not remain in the tissues of a stump, the muscle-fibers undergoing atrophy, yet the fibrous tissue matting and padding together of the parts is left in its place. (5) A single flap requires the maximum sacrifice of limb, one side of the limb furnishing the entire covering and the bone being consequently divided at a higher level.

Amputation by a Single Flap of Skin.—Technic.—Having incised through skin and fascia, this integumentary flap is dissected up from the muscles throughout, including all overlying fascia, and is retracted above the saw-line (or disarticulation-line, when the bone is sawed or disarticulated, and the flap dropped over the end of the limb, its terminal aspect being sutured to the transversely divided skin of the opposite side.

Resulting Stump.—It is very thinly covered, but as the skin so utilized is generally accustomed to pressure, the result is usually satisfactory.

Indications.—Such localities as the knee-joint (disarticulation by a single anterior flap) or the elbow-joint (disarticulation by a single posterior flap).

Comment.—(1) As this method is generally used in a disarticulation, a capsuloperiosteal covering may sometimes be provided. (2) Nutrition of a single flap of skin and muscle is more difficult to maintain than in the more ordinary methods, and the nutrition of a flap of skin alone is even harder. (3) Skin-flaps are more used now than formerly, because, owing to rarer suppuration, their vitality can be more counted upon.

Amputation by Equal Flaps of Skin and Muscle.—Technic.—The preliminaries being the same as in the ordinary circular amputation, two flaps are marked out, each having a width of base equal to the half-circumference at the saw-line and a length equal to three-fourths of the diameter of the limb at that same line. With a large scalpel incise along the outlined flaps, passing through skin and connective tissue. When these integumentary flaps have retracted, proceed to form the remainder of the flaps, cutting obliquely along the margin of the retracted skin in such a manner that the flaps will be bluntly (not thinly) beveled, directing the knife so that the beveling will be greatest (though not thin even here) at the tip and thickest toward the base, and coming down upon the bone, or bones, a distance below

the saw-line equal to a full diameter of the bone (or of the bigger bone) to allow for musculoperiosteal covering. At this level make a circular cut around the bone through the periosteum with a heavy knife, detach the musculoperiosteal covering of the bone upward to the saw-line, retract the soft parts, divide the bone, suture the musculoperiosteal covering, quilt the muscles, and suture the skin.

Resulting Stump.—As a rule, it is excellently covered by substantial tissues. The scar is terminolateral.

Indications.—In the continuity of limbs (between joints) where the bone or bones are equally covered with soft parts.

Comment.—(1) The simplest form of making double flaps is by two vertical incisions down the opposite sides of what has been begun as a circular method. (2) One flap may be cut from without inward, and the other by transfixion. (3) In very muscular limbs it makes the meeting of skin over the muscles easier if about 2.5 cm. (1 inch) of skin and fascia are dissected up from the muscle, after marking out and dividing the skin and fascia, and then cutting the muscles to the bone in a beveling fashion.

Amputation by Equal Flaps of Skin.—This operation is the same in general contour and dimensions of the flaps as the last, except that the covering here consists of skin only.

Technic.—Having incised through skin and fascia, upon the same lines as in the last form of amputation, the two equal flaps of integumentary tissues are dissected up to a level below the saw-line which will allow of providing a musculoperiosteal covering; at this level the muscles, after retracting the skin, are circularly divided down to the bone, this circular incision is continued, on the same level (one-half diameter of the bone below the saw-line) around and through the periosteum, the periosteum is then retracted, with the overlying muscles, to the saw-line, and the bone divided. The musculoperiosteal covering is then sutured over the bone, and the skin-margins sutured together.

The **resulting stump** is thinly covered, no muscle being present, but is generally satisfactory in the localities where adopted. The scar is terminolateral.

Indications.—Where a satisfactory muscle covering is hard to secure, as in the lower third of the forearm and leg and in the fingers, the tendons predominating in these localities.

Amputation by Unequal Flaps of Skin and Muscles.—**Technic.**—This amputation is identical, except as to the length of the flaps, with the amputation by equal flaps of skin and muscle.

The **resulting stump** is generally well covered, with the scar either entirely lateral or partly lateral and partly terminal, dependent upon the preponderance of one flap over the other.

Indications.—Thigh and arm throughout, and upper parts of forearm and leg.

Amputation by Unequal Flaps of Skin.—The coverings are of skin and fascia alone and are furnished by the two opposite aspects

of the limb, in the form of two flaps having equal bases and unequal lengths. This amputation is identical throughout with the amputation by equal flaps of skin, except as to the length of the flaps.

Amputation by Unequal Rectangular Flaps of Skin and Muscles (Teale's Method).—Technic.—Having fixed upon the saw-line, two flaps are marked out, having their bases at that line and extending downward as described below. Find the circumference of the limb at the saw-line. The longer flap is to have its length and its breadth equal to a half-circumference at the saw-line. The shorter flap is to be one-fourth of the length of the longer, and its breadth equal to the remaining half-circumference at the saw-line. The longer flap should be of the same width all the way down. The shorter flap will have a width at its free end equal to very nearly a half-circumference of the limb at the level where it terminates (as that level, in the case of the shorter flap, is so short a distance beneath the saw-line). Having marked out these flaps, which should be accurately measured, the vertical parts of the incision should be made from above downward, connected at their lower ends by the transverse incision which marks the limit of the longer flap, and by another transverse incision across the opposite half-circumference of the limb, at the proper level, marking off the lower limit of the shorter flap. These incisions at first involve skin and fascia only. When retraction has occurred (making a difference in the transverse incisions only), they are deepened throughout to the periosteum. The vertical limbs of the flaps are first cut to the periosteum, then the lower transverse limit of the longer flap, which is dissected up above the lower limit of the shorter flap, which in turn is cut transversely to the periosteum and dissected up. When a level below the saw-line is reached equal to a half-diameter of the bone at the saw-line, a circular incision is made through the periosteum and a musculoperiosteal covering raised. All the soft parts are now retracted above the saw-line and the bone divided. The musculoperiosteal covering is sutured. The longer flap is bent over the end of the bone, its end being sutured to the end of the shorter flap, the lateral aspects of the shorter flap are sutured to the lateral aspects of the longer, and the lateral aspects of the bent-over portion of the long flap are sutured to the contiguous lateral aspects of the unbent portion of the long flap. The muscles are quilted prior to suturing the skin. The part is well supported by splint, with only light pressure over the bent longer flap.

Resulting Stump.—An H-shaped cicatrix is formed upon the aspect of the limb furnishing the shorter flap. The end of the bone is well covered when the long flap contains a preponderance of muscle, less well covered when containing a preponderance of tendons.

Indications.—In the lower part of the leg (where the longer flap is taken from the anterior aspect), and sometimes in the lower forearm (where the longer flap comes from the posterior aspect).

Elliptical Method of Amputation.—This is not a distinct form

of amputation. It may be considered a variety of the circular method (an oblique circular), or, equally, a variety of single-flap amputation. It is circular, as to skin-incision; and flap, as to its manner of covering the stump and in the suturing. The skin-incision is in the form of an ellipse or a lozenge, the upper part of the ellipse being upon one aspect of the limb and the lower part upon the opposite, the lateral limbs of the figure crossing the lateral aspects of the limb to be amputated.

Technic.—Having fixed upon the saw-line (or line of disarticulation), a point is determined above this, on, say, the posterior aspect of the limb, which is just above the saw-line. This becomes the highest point of the ellipse. The point marking the lowest point of the ellipse is placed upon the opposite side of the limb, at a distance below the saw-line equal, approximately, to 1½ diameters of the limb at the saw-line (as there is but this one source of covering). Between these two points the lateral limbs of the ellipse pass, crossing the lateral aspects of the limb to be operated obliquely, from above downward, and so planned as to give a well-rounded convex termination of the ellipse below to be brought up and fitted into a corresponding concavity above. The incision first passes around the outline of the ellipse, through skin and fascia only. Around the lower three-fourths of the line of this retracted skin and fascia a second incision passes through the muscles to the bone. The soft parts (skin and muscles) forming the lower part of the ellipse (the part that is to remain attached to the limb which is to be retained) are now dissected up from the bone to a point sufficiently below the upper limit of the ellipse to allow a musculoperiosteal or capsuloperiosteal covering to be raised, and then on up to just below the upper limit of the ellipse (that is, to the saw-line or line of disarticulation). This large single mass of soft parts is well retracted, and the muscles on that aspect of the limb opposite to the one furnishing the muscles in the elliptical covering are circularly divided, and the limb sawed, or disarticulated, preserving the periosteum in the usual way. The lower convexity of the elliptical flap is now sutured into the upper concavity left by the part of the limb removed, the musculoperiosteal, or capsuloperiosteal, covering and the muscles being treated in the general manner by buried gut sutures, and the skin wound closed.

Resulting Stump.—The ellipse is generally taken from a locality which affords a plentiful covering for the extremity, which is thus well provided for. The scar is lateral.

Indications.—Chiefly used for disarticulations, especially at the elbow and wrist, and in the supramalleolar amputation.

Comment.—The muscle portion of the ellipse may be cut also by transfixion, though, as usual, less satisfactorily.

Irregular Methods of Amputation.—This is a special feature of modern surgery. Formerly amputations were done upon hard-and-fast lines. Now there is a marked tendency to allow the method of amputation to be determined by the special features and need of

the individual case, and, as a result, irregular amputations are more commonly done. These, while accomplishing the general indications, are not bound by any set rule, shape, or measurement. On common-sense ground the practical surgeon, therefore, should adapt his method of amputation to the case in point, rather than be bound by any fixed form of amputation. The greatest field for irregular forms of amputation is in cases of injury and deformity, rather than of disease.

Selection of Amputation Method.—Many considerations enter into the determination of the best method of amputation in a particular case, and the choice should be given to that method which promises to fulfil the greatest number of the following features:

Characteristics of Good Amputation Methods.—(1) Minimum sacrifice of healthy tissue; (2) best permanent bone-covering; (3) small wound area; (4) good blood-supply to stump; (5) favorably placed cicatrix; (6) efficient drainage; (7) simplicity of method; (8) vessels and muscles cut transversely; (9) possibility of getting satisfactory musculoperiosteal covering; (10) ease of exposing bone at saw-line; (11) ease of bringing soft parts together over bone without tension; (12) adjustability of artificial limb; (13) largest range of adaptability; (14) shapeliness of resulting stump; (15) rapidity of method.

Comment.—Circumstances may determine the selection of an amputation method known in advance not to be the best, for instance, owing to the increased mortality in approaching the trunk a limb may be removed, in a case where the vitality of the patient demands that every chance be given him, at a level which, while increasing his chances for life, may not furnish the best covering. Again, in amputating about the hand, it may conserve the interest of the patient better to be satisfied with even a partial flap and allow the remainder to heal by granulation, rather than remove an additional ½ cm. (¼ inch) of an important finger. Rapidity of method used to be the chief consideration, but is now the last in importance, except in special instances—other considerations taking precedence—the operation being done with deliberation and precision.

Features of the Circular Method of Amputating.—(1) Minimum sacrifice of bone and soft parts of any method. (2) Bone especially well covered in the infundibuliform variety. Conical stump sometimes follows retraction, especially in the cuff and modified varieties of the circular. (3) Smallest wound area of any method. (4) Tissues of stump well supplied with blood. (5) Cicatrix terminal. (6) Efficient drainage when sutured anteroposteriorly. (7) Most simple of any method. (8) Main vessels and muscles cut transversely. (9) Musculoperiosteal covering well provided. (10) Exposure of bone at saw-line not always easy. (11) Not always easy to bring soft parts together over bone. (12) Terminal cicatrix favorable for hollow artificial limbs; unfavorable for solid limbs of lower extremity. (13) Unfavorable for amputation following injury involving the aspects of

the limb to unequal heights. (14) Somewhat greater tendency to become conical. (15) Most rapid of any method.

Features of the Flap Method of Amputating.—(1) Greater sacrifice of bone and soft tissues (especially in unequal flaps). (2) Coverings of bone can be more largely regulated to suit demand. Conical stumps less apt to follow than after the cuff and modified forms of the circular. (3) Greater wound area. (4) In long flaps the blood-supply may not be so satisfactory. (5) Terminal or terminolateral cicatrix—can be planned as desired. (6) Drainage as efficient as in the circular if the flaps be lateral. Not so efficient if the flaps be anteroposterior. (7) Not so simple as the circular. (8) Muscles divided obliquely; vessels also, and latter may be split up. (9) Musculoperiosteal covering well provided. (10) Bone easily exposed at the saw-line. (11) Flaps easily brought together over bone. (12) Terminal cicatrix favorable for any hollow artificial limb. Terminal portion of terminolateral cicatrix pressed upon by solid lower limb, and lateral portion pressed upon by any hollow artificial limb. (13) Favorable for amputations following injury involving the aspects of the limbs unequally. Adaptable to any part of any limb. (14) Stump apt to be more shapely than that of the circular. (15) Less rapid than the circular.

Circumstances Influencing Death-rate after Amputation.—The death-rate is greater—(1) The nearer the amputation is to the trunk; (2) in the lower than in the upper limbs; (3) for injury than for disease; (4) in men than in women; (5) between the ages of five to fifteen than before or after.

PRIMARY, INTERMEDIATE, AND SECONDARY AMPUTATIONS.

In amputations done for disease the time for operation may be selected which will coincide with the patient's best condition to meet the procedure. Amputations done for injury are primary (performed immediately after the reception of the injury), intermediate (in the course of wound repair), or secondary (after healing). In primary amputations the operation should be done at once if the general condition of the patient permit. If the condition of shock (from physical effect and blood loss) contraindicates immediate interference, stimulation, intravenous infusion, direct transfusion of blood (p. 615), the application of heat, and the like, should be resorted to, and the limb removed during the reactionary period (generally within thirty-six hours). If the condition of shock is thought to be kept up by the damaged limb, amputation should be done at once, the above measures of revival being maintained the while.

ENDONEURAL INFILTRATION WITH LOCAL ANESTHETIZING AGENTS IN THE COURSE OF THE LARGER AMPUTATIONS.

It has been recommended, in addition to general anesthesia in performing amputations of greater importance, to "block" the larger

nerve-trunks as they are encountered in the course of the amputation by the local injection of cocain, eucain, or other anesthetizing solution. By this means it is thought that lowered blood-pressure and shock would be lessened.

THE AMPUTATION STUMP.

Qualities of a Good Stump.—Firm in consistency, well covered, insensitive, of regular and symmetric contour. The death-rate and the quality of the stump determine the success of any form of amputation. The following features are characteristic of a good stump and also indicate the changes which follow successful amputation:

Skin.—Not adherent, except at cicatrix. Capable of withstanding (and, preferably, accustomed to withstand) pressure. Plentifully supplied with blood.

Muscles.—The muscles of a stump are not retained as such; the muscle tissue disappears in greater part and is replaced by fibrous tissue. Exceptionally some muscle tissue remains and continues to function. The mass of fibrous tissue which replaces it, however, serves a useful purpose as padding over the end of the bone. In brief, muscle tissue tends to decrease and fibrous tissue to increase. Muscles and tendons either become incorporated in the cicatrix, form new attachments to bone, or retract out of the way.

Bone.—The ends of the bones become rounded and the medullary canals closed by fibrous tissue. The end of the bone may either dwindle and atrophy, or the periosteum may, exceptionally, deposit an excess of bone. The shaft of the bone in an amputated limb also atrophies somewhat.

Cartilage.—Following a disarticulation, the articular cartilage left atrophies and sometimes entirely disappears.

Nerves.—Also atrophy to a greater or less extent. The ends generally become bulbous, but give no trouble unless they become adherent to bone or cicatrix.

Vessels.—Share in the general atrophy, and dwindle to a size commensurate with the parts to be supplied. Ligated trunks become obliterated to their nearest branch. Collateral circulation is established.

Characteristics of a Bad Stump.—In contradistinction to the general qualities of a good stump, a bad stump may be flaccid, scantily covered, sensitive, of irregular contour, and may be further characterized by the following conditions:

Skin.—Thin, scanty, tightly drawn, adherent, puckered, cold or purple from improper circulation, ulcerated from the same cause, or from trophic changes, develop corns, and may become malignant.

Muscles.—See the changes mentioned in the last section.

Connective Tissue.—Bursæ may form.

Bone.—Osteitis, periosteitis, and necrosis may occur.

Two special forms of bad stump are met with:

Painful Stump.—This may be due to osteitis or periosteitis, but is generally due to compression of the nerve. The nerve may be directly pressed upon by new bone or fibrous tissue may be stretched over the stump, or may be the seat of neuritis. The end of a painful nerve is generally bulbous, but often normal-looking nerve-ends are sensitive and bulbous ones non-sensitive.

Conical Stump.—The end of the bone forms the apex of a cone which may be the result of one or more of the following causes—(1) Flaps cut too short or bone too long. (2) Sloughing or suppuration of the soft parts. (3) Postoperative contraction of muscles. (4) Growth of the bone from an active epiphysis in the young. This is especially to be anticipated in amputations of the upper arm and of the leg below the knee, since the chief growth of the humerus and tibia and fibula in length is at the upper end. Hence in the young the flaps should be made longer than usual.

Comment.—Unfavorable changes are less apt to occur in case of primary union than in the reverse.

Contractility of the Tissues of the Stump.—**Skin.**—The average contractility of the skin is equivalent to about one-third of its length. It is most contractile where thinnest, where the subcutaneous tissue is least, where its attachment to underlying parts is least, where it is least stretched by movements, and where the process of healing has been longest. It is least contractile where the opposite conditions exist.

Muscles.—The extremes of muscular contractility vary from a slight separation of divided parts up to a retraction of four-fifths of their length. Contractility is primary, where it occurs at the time of the operation, and secondary, where it occurs subsequent to the operation. Muscles contract most which are freest between origin and insertion, which have long fibers, and where the process of healing has been longest. The larger the muscle, the greater the amount left in the flap, and the younger and healthier the subject, the greater the contraction. Muscles contract least where the conditions are the reverse.

Skin, Fascia, and Muscles.—The average contractility of the mixed tissues of a flap, or covering, is generally equivalent to about one-third of the length of the flap or covering. Additional length, however, should be allowed in calculating the length of coverings—(1) When the transverse section of the bone is large as compared with the transverse section of the soft parts; (2) when the amputation is considerably below the origin of the muscle involved; (3) when secondary retraction is expected.

Position of Stump-cicatrices.—The cicatrix should be so placed as to be the least exposed to pressure after the healing of the wound.

With Reference to Their Position.—Scars may be terminal—at the end of the stump; lateral—on one or more sides of the stump; termino-lateral—occupying the end and side of the stump.

With Reference to Their Production.—The following methods of amputation produce the following kinds of scars: Circular is followed by terminal scar—elliptic, by lateral scar, if the ellipse be oblique, and terminal if the ellipse be nearly horizontal; oval, by terminolateral; racket, by terminolateral; single flap, by lateral scar; double flap, by terminal scar, if the flaps be equal, and lateral if the flaps be unequal.

Comment.—(1) Other things being equal, that method of amputation should be chosen which will bring the scar in the most favorable position for that particular case, and especially with reference to the subsequent functioning of the stump and its adaptability to an artificial limb. (2) In amputating in some situations the muscles of one group being so much stronger than those of another, will often draw a scar, terminal at the time of operation, much higher up upon one aspect than it will be drawn on the opposite aspect. Allowance for such an occurrence has, therefore, to be made.

Function of Amputation Stumps.—In the Upper Extremity.—The chief function of the stump in the upper extremity is range of movement and power to wield an artificial limb, rather than to bear pressure and weight. As the chief pressure of an artificial limb comes upon the lateral aspects of the stump, the scar of the stump in the upper extremity is best when terminally placed.

In the Lower Extremity.—The chief function of the stump in the lower extremity is to bear pressure and weight. As the chief pressure of a solid artificial limb comes upon the end of the stump, the scar of the stump in the lower extremity is best when laterally placed in those cases in which a solid artificial limb is to be worn. As, however, most modern artificial limbs for the lower extremity, for the better classes, are hollow, there is not now made the same difference as formerly.

The Modern Type of Artificial Limb.—While the above was particularly true of the older, cruder forms of artificial limbs (and is still true of the peg-leg), the modern forms of artificial limbs are nearly always made upon the basis of a light, hollow cone, and are so adjusted as largely to adapt themselves to the conditions found, and, generally speaking, most of the pressure is on the lateral aspects of the stump and living limb against the sides of the hollow cone of the artificial limb, so that pressure is exercised upon the lateral aspects of the living stump and limb rather than upon the end; and in the lower as well as in the upper extremity.

Comment.—A function of the stump of the upper extremity, especially about the hand, and more particularly of a woman, is to be as symmetrical and shapely as possible, in the case of partial sacrifice of that member. While in the case of a laborer it would certainly be better to sacrifice appearance to strength and utility, one might be urged to sacrifice strength for appearance in the case of a woman of the non-working class.

SITE OF AMPUTATION IN CONNECTION WITH THE RESULTING STUMP AND ITS ADAPTABILITY TO AN ARTIFICIAL LIMB.

The choice of the site of amputation is determined by the resulting mortality and the fitness of the stump for an artificial limb. Concerning the effect of the amputation site upon mortality, see Circumstances Influencing the Death-rate after Amputation (p. 802).

In general, the longer the stump, the more useful the limb. Considerable responsibility rests with the surgeon in choosing the site and technic of operation which will leave the patient the best stump, circumstances considered, adaptable to an artificial limb.

While formerly it was taught that we must save every fraction of limb possible, it is now regarded as better for the patient's interest to select that site and form of amputation furnishing a stump best suited to take an artificial limb of the widest range of function. In planning the form of skin-covering it is to be remembered that if the scar be not terminal, it should be somewhat posterior or lateral, rather than anterior, as the movement to force an artificial limb forward causes the apparatus to press upon an anterior scar. For the same reasons the ends of divided bones which lie near the skin, which is generally their anterior aspect, should be rounded, so as not to be pressed by the false limb.

In planning an efficient stump distal to a joint, sufficient length below the joint must be provided to bear upon and wield or swing the artificial limb. Every additional inch is here a matter of importance.

The primary function of the upper artificial limb is for prehension—of the lower, to bear weight and admit of locomotion.

As the main growth in the length of the humerus and tibia and fibula is from the upper epiphysis, amputation through the shaft of these bones, in the young, will almost certainly be followed by a conical stump, which will often require reamputation.

In the lower extremity an osteoplastic amputation is preferable where feasible, especially in operation for disease, where a deliberate calculation can be made.

The general tendency of the day in operating about the foot is to regard the foot as a whole, irrespective of joint-lines, and to amputate along improvised lines adapted to the special case.

Classic and irregular amputations through the tarsus, though condemned by artificial-limb-makers, and though supposed by some to yield too large a proportion of sensitive stumps, should be performed in preference to amputations above the ankle.

The lower third of the leg is the place of election in amputating through the leg, rather than the formerly given "hand's-breadth" below the knee-joint. In the latter case too limited a length of bone is left for good leverage in adapting a false limb. The site of choice is near the junction of the middle and lower thirds of the leg, thus leaving room for an artificial ankle-joint.

Under no circumstances amputate through the tibia higher than 8 cm. (3 inches) below its superior articular surface.

In amputating in the neighborhood of the knee-joint, one of the osteoplastic operations by which a piece of bone from the tibia is approximated to the sawn end of the femur in the condyloid region serves a useful purpose, furnishes a stump that will bear pressure well, and generally leaves room for the artificial knee-joint in an approximately normal position. Amputation through the thigh 8 cm. (3 inches) above the knee-joint gives ample room for an artificial joint in a normal position. Amputations through the thigh higher than its middle do not furnish as satisfactory a stump as those at and below this level. In operating above the knee, however, it is to be borne in mind that the weight is also borne by the ischioperineal parts.

SPECIAL AMPUTATIONS.

Amputation Through Last Phalanx of Fingers.—By Palmar Flap.—The covering consists of a single palmar flap of all the tissues down to the bone.

The position of the principals, in the case of all the amputations about the fingers, is as follows: The patient rests upon the back, the upper extremity held out from the body, or, better, supported on a

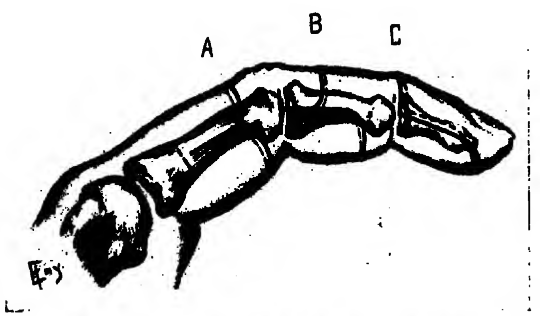


FIG. 329.—AMPUTATIONS ABOUT THE FINGERS.
A, Through first phalanx, by equal palmar and dorsal flaps; B, first interphalangeal joint, by long palmar and short dorsal flaps; C, second interphalangeal joint, by palmar flap.

small table, the hand pronated and fingers flexed while the dorsal incisions are made, and the hand supinated and fingers extended during the palmar incisions. The assistant stands in front of the surgeon, between him and the shoulder of the patient, steadying the hand with both of his own and holding the adjacent fingers out of the way. The surgeon holds the digit to be removed with the thumb and forefinger of his left hand, with the back of the thumb downward and his hand pronated during palmar incisions, and with his thumb upward and his hand supinated during dorsal incisions.

The space is so limited that the saw-line can be placed only between the matrix of the nail and the proximal end of the second phalanx.

The palmar incision extends from the saw-line downward along the lateral aspect of the phalanx, midway between the dorsal and palmar

surfaces, around the center of the pulp, and back to the saw-line on the opposite side. The dorsal incision connects the upper ends of the palmar incision, passing transversely over the dorsum with slight downward convexity. (For principle, see Fig. 329, C, and Fig. 330, C, where disarticulation at the last interphalangeal joint is shown by this method.)

Having outlined these incisions, carry the palmar incision to the bone, dissect up the palmar tissues down to the bone, deepen the dorsal incision to the bone, retract the soft parts in the entire circumference, and saw the phalanx with a fine saw, while holding the tip of the phalanx with bone-holding forceps (as there is generally too little room for the fingers of the operator to grasp). Ligate the palmar digital arteries on each side. Suture the deep flexor tendon to the periosteum or flap. Suture the palmar flap to the transverse dorsal line.

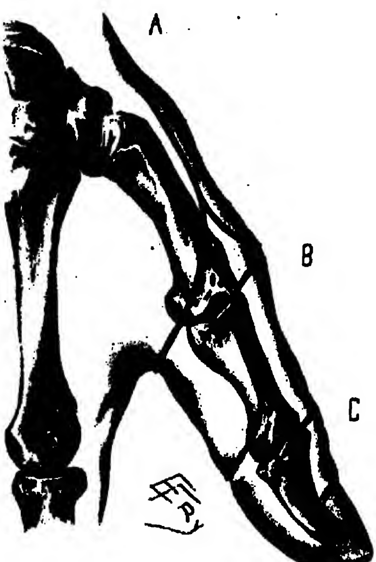


FIG. 330.—AMPUTATIONS ABOUT THE THUMB. A, Disarticulation of thumb at carpometacarpal joint by oval incision; B, disarticulation at metacarpophalangeal joint by oblique palmar flap; C, disarticulation at interphalangeal joint by palmar flap.

Disarticulation Through Second Interphalangeal Joints of Fingers.—By Palmar Flap.—The position is the same as for amputation through the last phalanx (p. 807). The landmark is the second interphalangeal joint-line.

The palmar incision begins opposite the joint-line, midway between the dorsal and palmar surfaces, passes down the lateral aspect for a distance equal to one and one-half diameters of the finger at the disarticulation-line, crosses the palmar aspect with bluntly rounded corners, and passes upward to the corresponding point on the opposite side of the finger. The dorsal incision connects the upper end of the palmar incision by a transverse incision made over the dorsum of the joint, with slight downward convexity (Fig. 329, C, and Fig. 330, C).

Having outlined these incisions through skin and fascia, carry the palmar incision to the bone on a line with retracted skin, and dissect the soft parts up from the bone. Deepen the dorsal incision to the bone along the line of the retracted skin, open the joint from the dorsum, and disarticulate from within outward. There is no theca here to close. Suture the deep flexor tendons into the neighboring tissues. Ligate the two digital arteries. Suture the palmar flap to the dorsal line.

Amputation Through Second Phalanx of Fingers.—By Palmar Flap.—The position is the same as for amputation through the last phalanx (p. 807).

The landmarks are the lines of the proximal and distal joints.

The palmar incision begins opposite the saw-line in the midlateral aspect of the finger, passes vertically downward a distance equivalent to one and one-half diameters of the finger at the saw-line, crosses the palmar aspect with bluntly rounded corners, passes vertically upward in the midlateral aspect of the opposite side to a point corresponding with the one of beginning. The dorsal incision connects the upper limits of the limbs of the palmar incision, passing transversely across the dorsum with slight downward convexity. (For principle, see Fig. 329, C, and Fig. 330, C, where disarticulation at the last interphalangeal joint is shown by this method.)

The above incisions are deepened to the bone, the palmar first and then the dorsal, on a line with the retracted skin. The soft parts are dissected off the bone back to the saw-line, and are retracted while the bone is being sawed. Ligate the digital arteries. In amputating distally to the upper third of the second phalanx, the superficial flexor tendon will retain its attachment. The deep flexor tendon will, however, be severed, and should be sutured into the mouth of the fibrous sheath (which ends at the middle of the second phalanx) and into neighboring periosteum and soft parts, if necessary—the closure of the sheath being accomplished in the process of anchoring the deep flexor tendon. The flap is then sutured in the usual way.

Disarticulation at First Interphalangeal Joints of Fingers.—By Palmar Flap.—The position is as in amputation through last phalanx of the finger (p. 807).

The landmark is the first interphalangeal joint-line.

The incisions are the same as for the disarticulation of a finger at the second interphalangeal joint-line by a palmar flap (p. 808, and for principle see Fig. 330, C).

The operation is the same, in principle, as the disarticulation at the second joint of the finger. Both the flexor tendons are here severed below their insertions, and the use of the proximal phalanx would be much interfered with unless these tendons were securely attached to the sheath, periosteum, or glenoid ligament of the stump.

Amputation Through First Phalanx of Fingers.—By Palmar Flap.—The position is as for amputation through the last phalanx (p. 807).

The landmarks are the lines of the metacarpophalangeal and first interphalangeal joints.

The incisions and operation are the same as for the amputation through the second phalanx (*vide supra*). For reference to the flexor tendons see under Disarticulation at the First Interphalangeal Joint by the Palmar Flap (*vide supra*).

Disarticulation of Fingers, in General, at Metacarpophalangeal Joints.—By Oval Method.—The queue is placed over the

dorsum of the joint, and the center of the oval passes across the palmar aspect of the web-line.

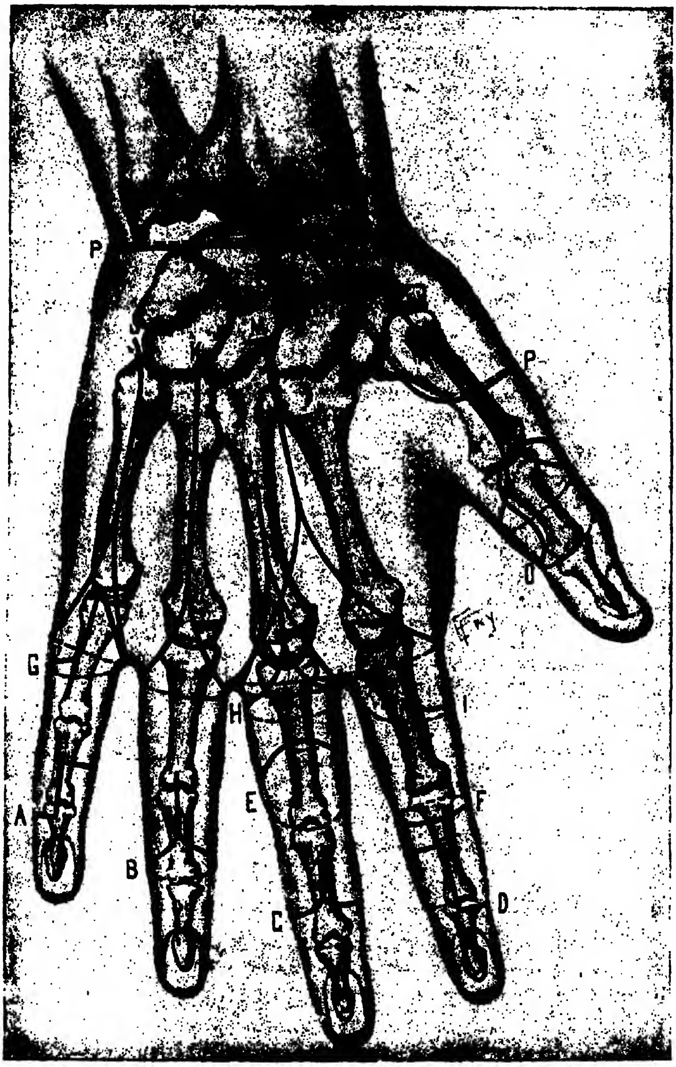


Fig. 331.—Amputations About the Fingers, Hand, and Wrist.

A, Through second phalanx of little finger, by single internal flap; B, at first interphalangeal joint, by oval method; C, through second phalanx, by equal lateral flaps; D, through second phalanx of index, by single external flap; E, through first phalanx, by oblique circular; F, through first [illegible] by externopalmar flap; J, of little finger at carpometacarpal joint, by racket method; K, same of ring finger; L, of middle finger and part of metacarpal, by racket method; M, of two inner fingers at carpometacarpal joints, by racket method; N, of thumb at carpometacarpal joint, by racket method; O, through metacarpophalangeal joint of thumb, by oblique palmar flap; P, P, at wrist-joint, by external flap.

The position is as for the amputation through the last phalanx (p. 807).

The landmarks are the head of the metacarpal, the metacarpophalangeal joint-line, and the web of the finger.

FIG. 332.—AMPUTATIONS ABOUT HAND AND WRIST.

A, Disarticulation of two inner fingers, together with their metacarpals, by curved racket incision; B, disarticulation at wrist by equal anterior and posterior flaps; C, D, oblique section of second and fifth metacarpals, as sometimes practised in disarticulation at metacarpophalangeal joints of first and fourth fingers; E, amputation of part of metacarpal by oval method, as sometimes performed in disarticulation at the metacarpophalangeal joints of the innermost and outermost fingers.

The incision begins just above the head of the metacarpal, on its dorsal aspect (in the position corresponding with its neck), passes down the median dorsal aspect over the prominence of the knuckle,

to just beyond the base of the first phalanx (which is about midway between the metacarpophalangeal joint-line and the free edge of the web)—at this point the hitherto median incision diverges into two symmetric limbs—each sweeping across the dorsolateral aspect of the finger to just below the junction of the finger with the web, and thence transversely across the palmar surface in the line of the crease, on a level with the free border of the web, coming to the opposite side just below the junction of the web with the finger. This rather extensive incision is best made with three strokes, from the commencement to the web of one side, from the point of divergence of the median line to the web of the opposite side, and across the palmar surface connecting the two limbs (Fig. 331, H, and Fig. 332, E).

The above incision through the skin and fascia is now deepened. The palmar portion is cut to the bone, while the finger is forcibly extended. The lateral portions are carried to the bone, cutting the lumbricales and interossei. The soft parts are retracted to the joint-line. The extensor tendons are then cut and the joint thus entered from the dorsum, the lateral ligaments and glenoid ligament being cut from within, and the disarticulation completed. The two digital arteries are tied and the synovial sheath closed. The edges of the sides of the oval are sutured in one vertical, anteroposterior line, in continuation with the queue of the incision. The splint applied should include the wrist-joint.

Disarticulation of Thumb at Metacarpophalangeal Joint.—By Oblique Palmar Flap (Farabeuf).—This method consists of two U-shaped incisions, the dorsal having its convexity upward, the palmar having its convexity downward, the limbs of each U passing, and obliquely meeting, on the lateral aspect of the thumb.

The position is the same as for the amputation through the last phalanx (p. 807).

The landmarks are the lines of the metacarpophalangeal and interphalangeal joints.

The convexity of the dorsal U is upward, and corresponds with the dorsal aspect of the metacarpophalangeal joint. The convexity of the palmar U is downward, and is placed just above the interphalangeal joint-line. Between these two rounded extremities the lateral limbs pass in an oblique direction along the lateral borders of the thumb, becoming continuous with each other (Fig. 330, B, and Fig. 331, O).

This incision is deepened throughout to the bone, along the line of the retracted skin; the extensor brevis pollicis and the extensor longus pollicis are divided over the metacarpophalangeal joint, and the flexor longus pollicis about the center of the first phalanx; the soft parts are freed back to the joint-line, the sesamoid bones are detached from the base of the first phalanx and left in the flap, the joint is entered from above, and disarticulation completed. The dorsalis pollicis and the two branches of the princeps pollicis are to be tied. The synovial sheath is closed. The convexity of the palmar

flap is sutured into the concavity of the dorsal wound, bringing the cicatrix well on to the dorsum and out of the way of pressure.

Disarticulation of Index-finger at Metacarpophalangeal Joint. —By Externopalmar Flap (Farabeuf).—This is really an oval method, so modified as to bring the cicatrix upon the internodorsal aspect of the metacarpophalangeal region, so that fingers and objects opposed to that aspect may not come into contact with the scar.

The position is the same as for amputation through the last phalanx (p. 807).

The landmarks are the metacarpophalangeal joint-line, the middle of the first phalanx, and the web.

The incision begins at the metacarpophalangeal joint-line, immediately over the median aspect of the extensor tendon, passes vertically down the median dorsal aspect of the finger, in the above relation to the extensor tendons, to the center of the first phalanx, thence sweeps across the lateral and palmar aspects to the web, and thence passes in a straight line, by the shortest route, up the inner side of the finger to the place of beginning (Fig. 331, I).

This superficial incision is deepened to the bone, the soft parts retracted to the joint-line, disarticulation effected, and the operation completed as in the simple oval method. The digital, dorsalis indicis, and the radialis indicis arteries are to be tied. The flexor sheath is to be closed, and the parts so sutured as to cause the cicatrix to occupy the position of the straight portion of the incision upon the internodorsal aspect.

Disarticulation of Little Finger at Metacarpophalangeal Joint.—By Internopalmar Flap (Farabeuf).—This, also, is a modification of the oval method, so calculated as to bring the cicatrix upon the externodorsal aspect of the metacarpophalangeal region that non-scar tissue may come into contact with objects which press the stump.

The position and landmarks are the same as in the last operation.

The incision begins at the metacarpophalangeal joint-line, immediately over the median aspect of the extensor tendon, passes vertically down the dorsal aspect of the finger, in the above relation to the extensor tendon, to the center of the first phalanx, thence sweeps across lateral and palmar aspects of the finger to the web, and thence passes in a straight line, by the shortest route, up the radial side of the finger to the place of beginning (Fig. 331, G).

The steps of the disarticulation are completed as in the corresponding operation just described upon the index-finger, the reverse of which this is in every respect. Two digital arteries are to be tied. The parts are to be so sutured as to cause the cicatrix to occupy the position of the straight portion of the incision, upon the externodorsal aspect of the region, buried in the groove formed by the adjacent finger.

Amputation of the Fingers in General with Parts of Their Metacarpals (*By Racket Method*).—The finger is removed as one continuous whole at the line of section of the metacarpal.

The position is the same as for amputation through the last phalanx (p. 807).

The landmarks are the outline of the dorsal aspect of the metacarpal, the carpometacarpal joint, and the webs of the fingers.

The incision begins over the dorsum of the metacarpal, a short distance above the point at which the bone is to be sawed, passes thence downward over the middle of the dorsal aspect until the neck of the metacarpal is reached, whence the median line diverges into two limbs, each limb passing down the dorsolateral aspect of the finger to just below the junction of the web and the finger, whence each limb crosses immediately in front of the digitopalmar crease to meet in the palmar aspect of the finger (Fig. 331, L).

The incision is deepened to the bone on the line of the retracted skin. The extensor tendons are divided near the upper end of the vertical incision. The sides of the shaft of the metacarpal are carefully cleared, hugging the bone in the process. The region of the metacarpophalangeal joint is also freed, and the flexor tendons divided near the neck of the metacarpal, while the finger is forcibly extended. The shaft of the metacarpal is further cleared up to the saw-line, the finger being held in extreme extension. The Gigli or chain saw is now passed beneath the metacarpal, while the soft parts are held out of the way, and the bone sawed so as to bevel it from below upward and toward the dorsum. The digital arteries are divided and are to be tied. The synovial sheath of the flexor tendons should be closed with gut sutures. The wound is sutured in a single median line upon the dorsal aspect.

Disarticulation of an Inner Finger with its Entire Metacarpal (*By Racket Incision*).—The finger is removed as one continuous whole at the carpometacarpal articulation.

The position is the same as in the preceding operations.

The landmarks are the outline of the dorsal aspect of the carpometacarpal articulation and the metacarpal bone.

The incision begins just above the carpometacarpal joint, passes down the median dorsal aspect of the metacarpal until the neck is reached, thence diverges into two limbs, each limb running over the dorsolateral aspect of the finger to just below the junction of the web and the finger, whence each limb crosses the digitopalmar crease to meet in the center of the palmar aspect of the finger. If necessary for the purpose of aiding disarticulation at the carpometacarpal joint, a short transverse incision may be made at a right angle to the upper end of the queue (Fig. 331, K).

This incision is now deepened on the line of the retracted skin and fascia. The shaft of the metacarpal and the metacarpophalangeal joint are carefully cleared, hugging the bones as carefully as possible, while an assistant keeps the finger in the position of extreme extension.

The extensor tendons are divided as near the upper limit of the queue as possible, the flexor tendons near the neck of the metacarpal. The sides of the metacarpal are now bared up toward the carpometacarpal articulation, using special care in the palmar region. The ligaments of the intermetacarpal joints and the carpometacarpal joints are divided by carefully thrusting a knife between the sides of the bases of the metacarpals and between the metacarpals and carpal bones, working from the dorsum of the hand. The disarticulation is completed by forcibly turning back the finger upon the dorsum of the hand, completing with a knife the division of any undivided ligaments, insertions of tendons, or palmar structures. The synovial sheaths of flexor tendons should be sutured with catgut if possible. Tie the two digital arteries, and suture the wound in a single median line upon its dorsal aspect.

Disarticulation of Thumb with its Entire Metacarpal *(By Racket Incision)*.—The operation consists in the removal of the thumb, together with its metacarpal, at the carpometacarpal joint.

The position is the same as for the fingers, except that the hand is held midway between pronation and supination.

The landmarks are the outline of the dorsal aspect of the metacarpal and the carpometacarpal joint.

The incision begins just above the carpometacarpal joint-line, in the mid-dorsal aspect of the metacarpal, passing into the "snuff-box," if at all, with great care, and, at first, very superficially, on account of the radial artery. The incision then passes down the center of the dorsum of the thumb to the neck of the metacarpal, and here divides into the two limbs of an oval, which part to encircle the head of the metacarpal, crossing the palmar apsect of the thumb on a level with the free edge of the web, the outer (radial) of the diverging limbs following the dorsal aspect a little further down before sweeping over the lateral aspect than does the inner (ulnar) limb (Fig. 330, A, and Fig. 331, N).

This incision is deepened on the line of the retracted skin and fascia. The extensor tendons of the first and second phalanges are cut as long as possible, so as to be sutured into the wound. The dorsum and sides of the metacarpal are cleared of soft parts, hugging the bone. The thumb is extended and abducted, and the muscles attached to the base of the first phalanx are divided near the sesamoid bone, preserving the thenar muscles as far as possible. The palmar aspect of the metacarpal is cleared while an assistant rotates the thumb from side to side, working as near the bone as possible. The flexor longus pollicis tendon is divided low down, so that it may be sutured into the wound. Disarticulation is accomplished by severing the binding ligaments and the extensor ossis metacarpi pollicis, while the thumb is flexed into the palm, opening the joint from the dorsum, the thumb being then rotated in different directions to complete the disarticulation. Suture the sheath of the flexor tendon. Tie the arteria princeps pollicis, or its two branches, and the dorsalis pollicis.

Quilt the muscles, suturing the flexor, extensor, and thenar tendons and muscles into the wound. The cicatrix will run in a dorsal median line.

Disarticulation of Two Contiguous Inside Fingers with their Entire Metacarpals (*By Racket Incision*).—The operation is the same in principle as that for the removal of a single finger and its metacarpal.

A vertical incision begins just above a carpometacarpal joint-line and between the bases of two contiguous metacarpals, passes down the back of the hand, midway between the two metacarpals for about one-half of their length, then divides into the two limbs of an oval or racket, the radial limb passing to the radial side of the outer of the two fingers to be removed, the ulnar limb to the ulnar side of the

Fig. 333.—Showing the Relations of the Various Metacarpal to the Corresponding Carpal Bones, as Guides in Disarticulating the Metacarpals from the Carpals and the Adjacent Metacarpals.

inner of the two fingers to be removed, to the junction of the fingers and webs, thence both limbs cross and meet beneath the fingers in the digitopalmar crease.

The incision is deepened, the metacarpals cleared, the tendons cut long, disarticulation accomplished, and the operation completed just as in the disarticulation of a single finger and its metacarpal. The flexor and extensor tendons are to be sutured into the wound (Fig. 331, M).

Disarticulation of Two Contiguous Outside Fingers with their Entire Metacarpals (*By Racket Incision*).—The operation is the same, in the main, as for the disarticulation of any two contiguous inside fingers with their metacarpals.

The incision may be planned exactly as in the preceding operation, or the queue of the incision may be curvilinear, beginning over the

carpometacarpal joint of the little finger and curving nearer the shaft of the fourth metacarpal before the limbs of the racket begin (or beginning over the carpometacarpal joint of the thumb and curving nearer the shaft of the second metacarpal before the limbs of the racket commence, in the case of the two outermost metacarpals), as shown in Fig. 332, A.

The operation is completed as in the last case.

Disarticulation of all the Fingers, Excluding the Thumb, with their Entire Metacarpals (*By Anterior Ellipse*).—This is, practically, a palmar covering whose convex anterior border fits into the concave wound on the dorsum of the hand. It is sometimes called the short palmar flap method.

The position is as for the amputations upon the fingers in general (p. 814).

The landmarks are the base of the fifth metacarpal (marking the point at which the ellipse crosses the ulnar border of the hand), a point midway between the central crease of the hand and the level of the outstretched thumb (marking the point at which the ellipse crosses the radial border of the hand), and the carpometacarpal joint-line.

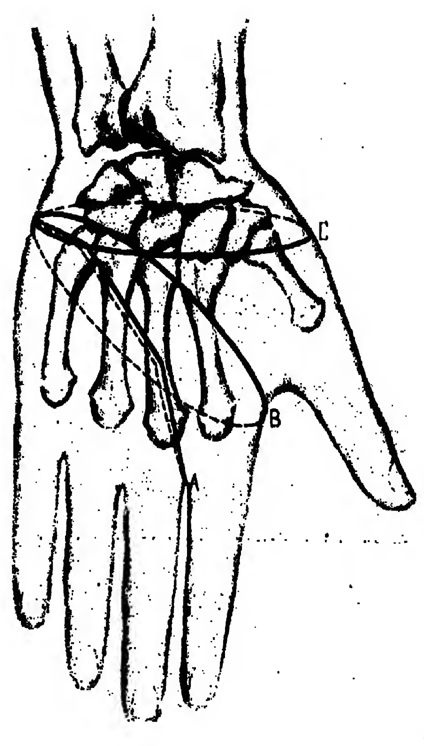


FIG. 334.—AMPUTATIONS ABOUT THE HAND.

A, Disarticulation of three inner fingers, with their metacarpals, by equal dorsal and palmar flaps; B, Disarticulation of all the fingers, except thumb, with their metacarpals, by anterior ellipse; C, Disarticulation at wrist-joint by circular method. (Dorsal view.)

The palmar incision passes between the two above points, with a downward convexity, whose lower part reaches below the middle of the metacarpals. The dorsal incision also passes between the same two points, with an upward convexity whose highest point corresponds with the bases of the two inner metacarpals (Fig. 334, B).

These incisions are deepened to the bone. The flexor and extensor tendons are cut long. The soft parts are cleared up to the carpometacarpal joint-line, the metacarpals are disarticulated from the carpals, and the second metacarpal from the first metacarpal, cutting the dorsal ligaments by flexing and the palmar ligaments by extending the hand. Tie the palmar digital, palmar interosseous, dorsalis

indicis, radialis indicis, and palmar arches, if severed. Close the flexor sheaths, suture the flexor and extensor tendons into the wound, and suture the convex palmar flap to the concave dorsal wound.

Disarticulation at the Wrist-joint (*By Anterior Ellipse*).—The covering raised is, practically, an anterior flap. The idea of the ellipse is appreciated after marking the outline, as given below, and then viewing it from the radial or ulnar aspect of the hand.

The position of the patient is upon the back, with forearm abducted horizontally, hand pronated or supinated, as indicated by the stage of the operation. The surgeon sits or stands facing the patient's hand. An assistant steadies the limb from above, and holds the parts out of the way.

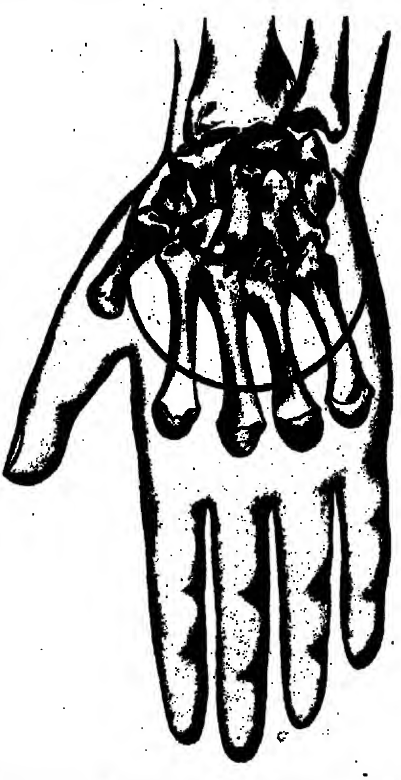


FIG. 335.—DISARTICULATION AT THE WRIST-JOINT BY THE ANTERIOR ELLIPTICAL METHOD. (Palmar view.)

The landmarks are the line of the wrist-joint, pisiform, base of fifth metacarpal, and the carpometacarpal joint of the thumb.

The highest point of the ellipse is upon the dorsum, 1.3 cm. (½ inch) below the line of the wrist-joint, and on a line with the middle finger. The lowest point of the ellipse is upon the palm, 6.3 cm. (2½ inches) below the line of wrist-joint, and on a line with the middle finger. The inner portion of the ellipse crosses the ulnar border of the hand between the pisiform bone and the base of the fifth metacarpal. The outer portion of the ellipse crosses the radial border of the hand at the carpometacarpal joint-line of the thumb. The entire incision has, therefore, a downward convexity upon the palm and an upward convexity upon the dorsum, and passes through the four above-mentioned points (Fig. 335).

Supinating the hand while incising the palm, and pronating it while making the dorsal incisions, this entire ellipse, which has been made through the skin and fascia at first, is now deepened throughout. The dorsal integuments are first dissected to the joint-line. The hand is flexed, and the extensor tendons, posterior ligament, and lateral ligaments are cut, and the joint opened and then the anterior ligaments. First one and then the other lateral border of the hand are made to

present, and the lateral parts of the ellipse carried to the bones. The knife is then carried between the flexor tendons and the carpus, from above and within, and made to clear out the hollow of the carpus in the act of cutting its way obliquely from above downward and outward to the margin of the palmar incision through the skin, and the hand thus severed from the arm. All loose tendons and nerves are to be cut. The following arteries are to be tied: radial, ulnar (below the deep branch), the deep branch of the ulnar, and the superficialis volæ. The deep palmar arch and the part of the superficial palmar arch are removed with the hand. The convex palmar flap is sutured into the concave wound at the back of the wrist.

Disarticulation at the Wrist-joint (*By External Lateral or Radial Flap—Dubrueil's Method*).—A saddle-shaped flap of the skin and muscles is raised from the metacarpal region of the thumb, and approximated to the disarticulated ends of the radius and ulna.

FIG. 336.—DISARTICULATION AT THE WRIST-JOINT BY THE PALMAR FLAP METHOD. (Palmar view.)

The position is the same as in the disarticulation by the elliptical method (p. 818). The landmarks are the wrist-joint and the first metacarpal.

The flap incision begins on the back of the wrist, about 6 mm. (¼ inch) below the wrist-joint line, and at the junction of the outer and middle thirds of that line, passes thence downward upon the dorsal aspect of the thumb, thence rounds outward to cross the first metacarpal transversely about its middle (remaining, up to the point of rounding outward, as far from the outer border of the hand as at the beginning). The incision now passes upward correspondingly on the inner aspect of the thumb, following the inner part of the thenar eminence, to a point about 6 mm. (about ¼ inch) below the wrist-joint line, at the junction of the outer and middle thirds of that line on the palmar surface. The disarticulating incision is made by joining the two upper ends of this flap by a transverse incision passing directly around the inner aspect of the wrist-joint (Fig. 331, P, P).

The thenar incision forming the flap is deepened—the soft parts

are dissected from the metacarpal and as much of the thenar muscles as possible is taken. The soft parts upon the inner aspect of the wrist are divided to the bone by the circular incision on a level with the base of the flap. Disarticulation is accomplished from the dorsal and inner aspect toward the palmar and outer. The following arteries are to be tied: superficial and deep palmar arches; dorsalis and radialis indicis and ulnar. The tendons and nerves are treated as in the preceding operation upon the wrist. The external or thenar flap is now brought transversely across the articular ends of the radius and ulna, and sutured to the circularly divided parts.

Amputation of Lower Third of Forearm (*By Modified Circular Method*).—Two short flaps of skin and fascia are turned back and the muscles are then circularly divided at the level of the retracted skin-and-fascia flaps.

The patient is in the supine position, near the edge of the table, with the upper limb abducted to a right angle, and held by an assistant in supination during anterior incisions, and in pronation, or vertically, during posterior incisions. The surgeon stands to the outer side of the right limb and to the inner side of the left.

The landmark is the saw-line.

The total covering is to be one and one-half the diameter of the forearm at the saw-line. The anterior and posterior aspects will each furnish three-fourths of a diameter. One-half of this three-fourth diameter length will be of skin and fascia alone, on each side, the remaining half of the skin, fascia, and muscle. Therefore a point below the saw-line equal to three-fourths of a diameter at the saw-line will mark the lowest limit from which the covering is to be divided. Two small flaps are incised, each having a base equal to a half-circumference, and a length equal to half (the lower half) of the distance between the saw-line and the lowest limit of the skin incision. These flaps will be bluntly rounded at their lower ends (Fig. 337, A).

Dissect up the integumentary flaps half-way to the saw-line, retract them, and, on a level with the retracted flaps, circularly divide the muscles to the bone. This circular incision also divides the periosteum and interosseous membrane. The muscles and periosteum are then retracted to the saw-line and the bones divided, completing the section of the more movable radius first. Tie the radial, ulnar, anterior and posterior interosseous arteries. Stitch the musculo-periosteal covering over the bones. Quilt the muscles or tendons of the anterior to those of the posterior aspect of the forearm, if possible. Suture the integumentary coverings in a straight line anteroposteriorly.

Amputation of Upper Two-thirds of Forearm (*By Equal Anterior and Posterior Flaps*).—The anterior and posterior aspects of the forearm furnish equal U-shaped flaps of skin and muscle, the anterior largely composed of supinator longus and flexors, the posterior largely made up of extensors.

The position of the principals is the same as in the operation last described. The landmark is the saw-line.

An anterior and a posterior U-shaped flap are incised on the respective aspects of the forearm, the base of each flap at the saw-line being equal to a half-circumference of the limb at that line, and the length of each equal to three-fourths of a diameter, the hand being supinated in making the anterior flap, and the forearm vertical in making the posterior flap (Fig. 337, B).

Having cut through the skin and fascia in outlining the flaps, these incisions are now deepened upon the line of the retracted skin, beginning at the ulnar side of the anterior flap in the case of the

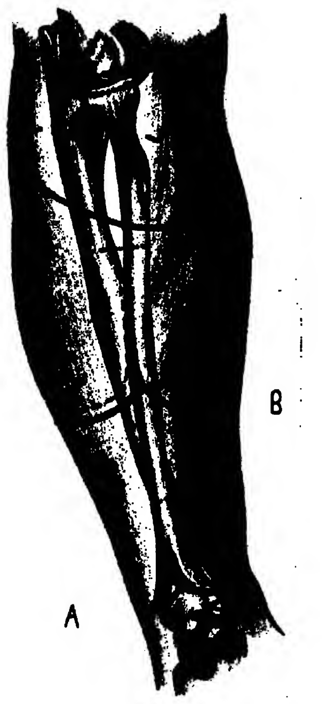


FIG. 337.—AMPUTATIONS THROUGH THE FOREARM AND AT THE ELBOW.

A, Through lower part of forearm by modified circular; B, through upper forearm by equal anterior and posterior flaps; C, disarticulation at elbow-joint by oblique circular method.

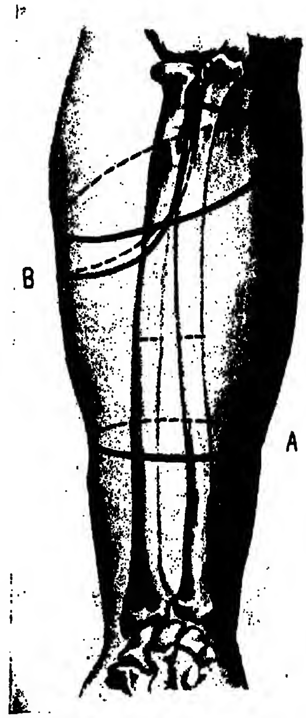


FIG. 338.—AMPUTATIONS ABOUT FOREARM AND ELBOW.

A, Through middle of forearm, by circular method; B, at elbow-joint, by single external flap; C, at elbow, by oblique circular method.

right arm, and on the radial side in the case of the left arm. The vertical ulnar incision will involve the flexor carpi ulnaris and flexor profundus; the vertical radial incision will involve the two radial carpal extensors, both vertical incisions passing directly to the bones. The muscles on the anterior and posterior aspects of the forearm, at the lower rounded extremities of the flaps, are cut from without inward in such a manner as to bevel them slightly. The entire flaps are now raised from the bones up to a point sufficiently below the saw-line to furnish a musculoperiosteal covering, at which level the periosteum

is circularly divided around the bones, the interosseous membrane cut transversely, and the musculoperiosteal covering freed to the saw-line. The soft parts are then retracted and the bones sawed. The radial, ulnar, and anterior and posterior interosseous arteries are tied. The median, radial, and ulnar nerves should be cut short, or even dissected from the flap. The musculoperiosteal covering is sutured and the muscles quilted, and the integuments sutured in the lateral line.

Disarticulation at Elbow-joint (*By Anterior Ellipse—Farabeuf*).—The covering is, essentially, an anterior flap, the idea of the ellipse being gotten in viewing the outlined incision laterally. The

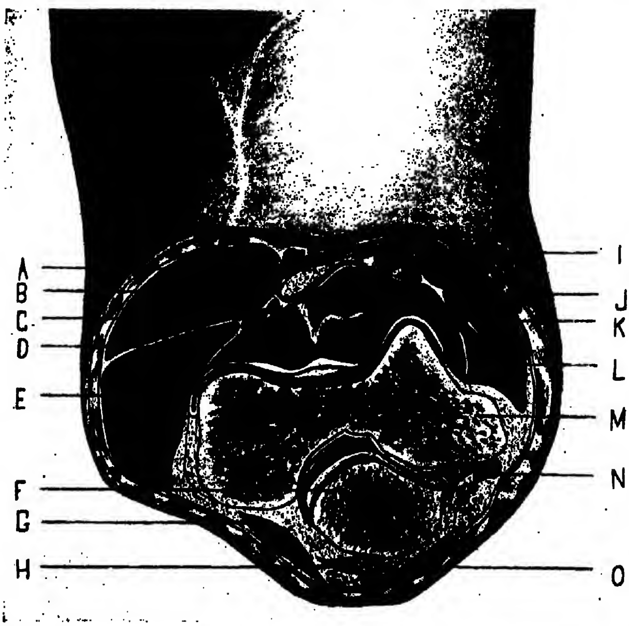


FIG. 339.—TRANSVERSE SECTION THROUGH THE CONDYLOID EXPANSION OF THE RIGHT ARM. A, Biceps tendon; B, Supinator longus; C, Musculospiral nerve and superior profunda artery; D, Brachialis anticus; E, Extensor carpi radialis longior; F, Olecranon ; G, Anconeus; H, Triceps; I, Brachial artery, venæ comites, and median basilic vein; J, Pronator radii teres; K, Median nerve; L, Flexor carpi radialis; M, Condyloid expansion of humerus; N, Ulnar nerve; O, Olecranon bursa. (Cross-section modified from Braune.)

lower anterior convexity of the covering is sutured into the upper posterior concavity.

The position is given in the course of the operation. The landmarks are the joint-line, the prominence of the olecranon, and the eminence of the supinator longus on the anterior aspect of the forearm.

The highest point of the ellipse is posterior, over the prominence of the olecranon. The lowest point of the ellipse is anterior, over the eminence of the supinator longus, just above the middle of the forearm. Midway between the upper and the lower rounded ends of the ellipse the lateral borders of the ellipse pass along the midlateral aspects of the forearm (Fig. 340, A).

The surgeon stands on the left of either right or left elbow (which will place the patient's elbow on his right), grasping the patient's wrist with his left hand, and, flexing the elbow, so rotates the limb as to make the entire elliptical incision without relaxing his hold of the wrist or removing the knife, which passes from olecranon to olecranon. Taking the right limb, for instance, turn the slightly flexed elbow so as to present the radial aspect, enter the knife at the apex of the olecranon, pass down the radial lateral aspect across the lower end of the ellipse on the anterior aspect of the forearm (with the forearm

FIG. 340.—DISARTICULATIONS AT THE ELBOW-JOINT.

A, By anterior ellipse; B, By long antero-internal and short postero-external flaps (practically a long internal and short external flap).

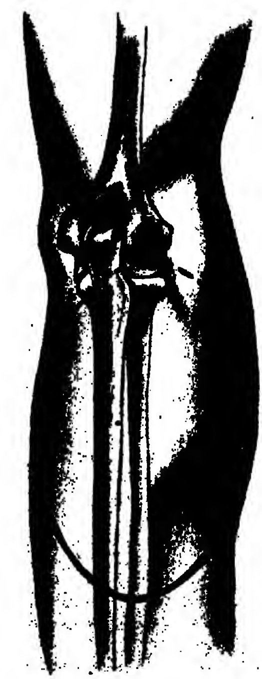


FIG. 341.—DISARTICULATION AT THE ELBOW BY THE POSTERIOR ELLIPTICAL METHOD.

extended and supine), then along the inner aspect (with the elbow again flexed and the inner aspect of the forearm thereby made to present), and upward to the olecranon. The skin and fascia upon the proximal side of the lower end of this incision are now further retracted by hand. On the line of the retracted integuments the muscles are cut obliquely from without inward and upward toward the joint, in such a manner as to bevel the anterior covering which is being raised, and, at the same time, raise as much of a musculoperiosteal covering as possible. This anterior flap is dissected and retracted upward to

the joint-line. The anterior, lateral, and posterior ligaments of the joint are now cut in order. The triceps and any remaining posterior tissues are severed. The radial, ulnar, interosseous, muscular branches, and, possibly, the posterior ulnar recurrent and terminations of the superior and inferior profunda are ligated. Quilt the muscles in the anterior flap to the fascia along the margins of the upper half of the ellipse. Suture the integumentary tissues of the convex lower end of the flap into those of the upper concavity. Temporary drainage is indicated.

Disarticulation at Elbow-joint (*By Posterior Ellipse*).—The covering is, practically, a posterior flap, the idea of the ellipse being understood by taking a lateral view of the incision.

FIG. 342.—DISARTICULATION AT ELBOW BY LONG ANTERIOR AND SHORT POSTERIOR FLAPS.

FIG. 343.—DISARTICULATION AT ELBOW BY LONG POSTERIOR AND SHORT ANTERIOR FLAPS.

The position of the principals is given in the course of the operation.

The landmarks are the joint-line and the tip of the olecranon.

The highest point of the ellipse is anterior, opposite the lower margin of the joint-line. The lowest point is posterior, between 8 and 10 cm. (3 and 4 inches) below the joint-line. Midway between the upper and lower ends of the rounded ellipse the lateral borders of the ellipse pass along the midlateral aspects of the forearm. With the elbow flexed to an angle of 135 degrees, the lateral parts of the incision will be parallel with the prolonged anterior aspect of the arm (Fig. 341).

The surgeon stands on the right side of either elbow, grasping the patient's wrist with the left hand (the back of his hand uppermost and his thumb toward the patient's fingers), and manipulates the elbow so as to complete the incision at one sweep, beginning the incision at the anterior joint-line, with the elbow flexed at the above angle, passing down the inner aspect (while that part is manipulated so as to render it prominent), crossing the dorsal aspect (while the forearm is held vertical), and ascending the outer aspect (while that aspect is made prominent) to the place of beginning. Upon the line of the retracted integuments the deeper parts are now cut. Those along the posterior aspect of the ellipse are divided, together with the periosteum, and including the anconeus and insertion of the triceps

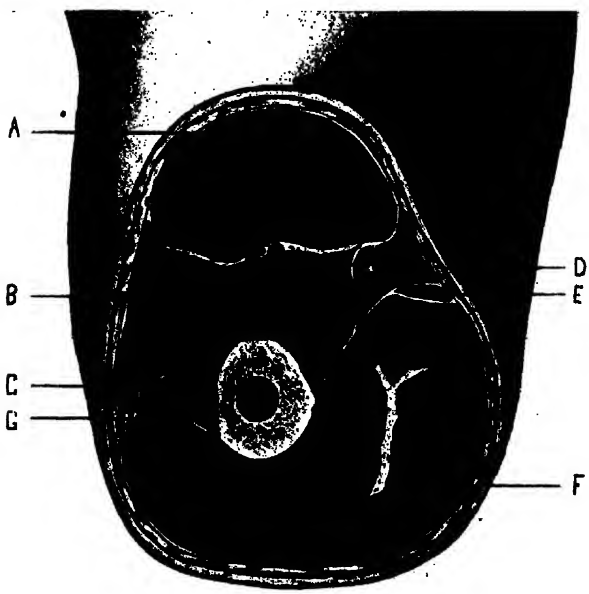


Fig. 344.—Transverse Section through the Lower Third of the Right Arm.

A, Biceps; B, brachialis anticus; C, musculospiral nerve and superior profunda artery, supinator longus; D, brachial artery, venæ comites, basilic vein, and median nerve; E, ulnar nerve and inferior profunda artery; F, triceps. (Cross-section modified from Braune.)

when reached, and are dissected up to just above the tip of the olecranon. The deeper parts along the anterior portion of the ellipse are then divided, corresponding with the joint-line, and the capsule of the joint divided transversely, followed by the division of the lateral ligaments and posterior portion of the capsule (unless a capsuloperiosteal covering can be raised). Tie the brachial, posterior interosseous, muscular branches, and terminations of the superior and inferior profunda. Cut the ulnar nerve especially short. Quilt the muscles in the posterior flap to the fascia along the margins of the upper half of the ellipse. Drain temporarily. Suture the integuments of the lower portion of the ellipse (the convexity) of the posterior flap to the upper concavity of the incision.

Amputation through Lower Third of Arm (*By Modified Circular Method*).—Two short skin-flaps are cut and turned back and the muscles divided circularly in the infundibular manner.

The patient is supine at the edge of the table, the limb horizontally abducted over the edge of the table during anterior incisions, and held vertically with bent elbow, or drawn over the chest, in dorsal incisions. The surgeon stands on the outer side of the right and

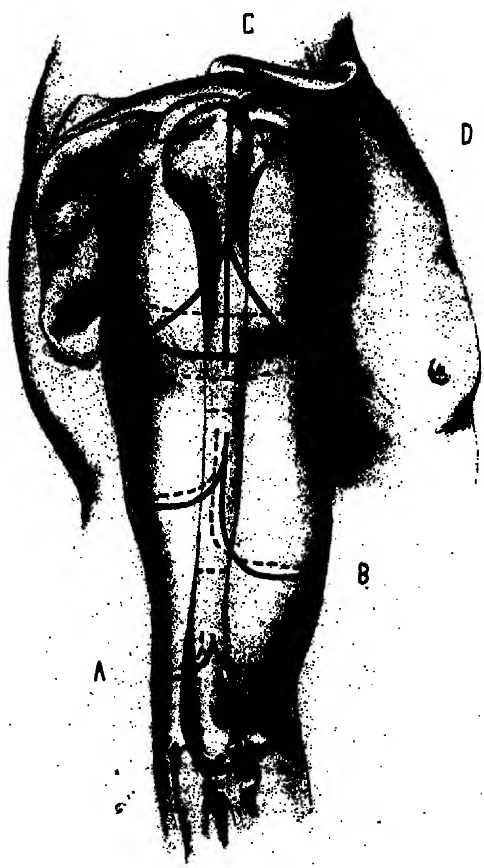


FIG. 345.—AMPUTATIONS THROUGH ARM AND AT SHOULDER.

A, Through lower part of arm, by modified circular; B, through upper part of arm, by long anterior and short posterior flaps; C, at shoulder-joint by external racket method (Larrey's operation); D, D, at shoulder by external or deltoid flap (Dupuytren's operation).

inner side of the left limb. The assistants steady the limb above and below the site of amputation. The landmark is the saw-line.

The lowest limit of the skin-incision is placed at a distance below the saw-line equal to three-fourths of the diameter of the limb at the saw-line (thus securing a covering of one and one-half diameters). Of this total distance the small flaps will occupy, approximately, the lower one-third. These flaps are generally anterior and posterior

(but may be lateral, or in any intermediate position, as the local conditions may demand). Their base is one-half the circumference of the limb—they pass down the lateral aspects of the limb to nearly their lower limit, when they bluntly round transversely across the limb to a corresponding point on the opposite side. Anterior and posterior flaps are similar (Fig. 345, A).

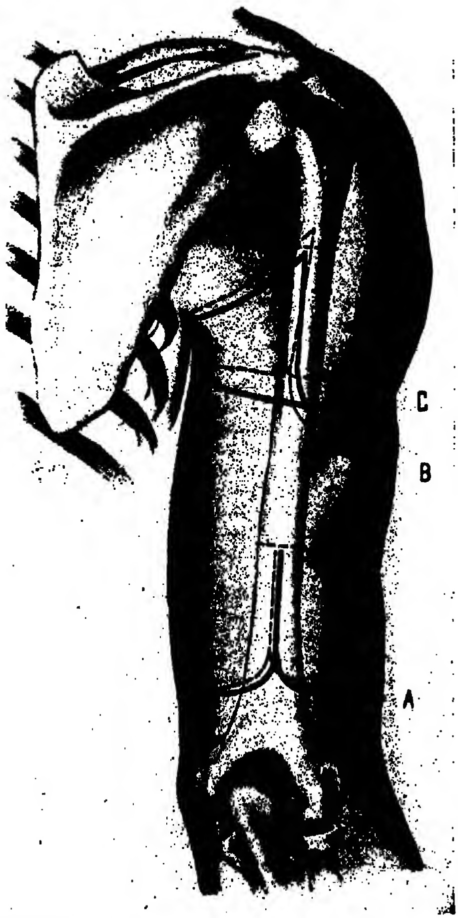


FIG. 346.—AMPUTATIONS ABOUT ARM AND AT SHOULDER.
A, Through lower part of arm by equal lateral flaps; B, through surgical neck of humerus by single external flap; C, at shoulder-joint by Furneaux Jordan's method.

These flaps of the skin and the fascia are freed up to their base and turned back as cuffs. Here the more superficial muscles are circularly divided, and retracted in turn. Upon the line of these retracted superficial muscles, the deeper muscles are cut to the bone, at a level still beneath the saw-line. This last circular division also divides the periosteum around the entire bone. All the soft parts, including the periosteum, are now freed up to the saw-line and the bone divided.

Tie the brachial, superior profunda, inferior profunda, muscular, and possibly the anastomotica magna branches. See that the musculospiral nerve is cleanly divided, and excise any portion of it apt to be pressed upon in bending the flap over the end of the bone. Suture the musculoperiosteal covering. Quilt the muscles. Suture the flaps in a lateral line.

Amputation of Arm at Surgical Neck of Humerus (*By Single External Flap*).—A U-shaped flap, composed chiefly of deltoid, is raised from the outer aspect of the arm, while the parts on the inner aspect are divided transversely, or with slight downward convexity, on a level with the upper limit of the limbs of the flap.

The position is the same as in the above operations, the limb being drawn well away from the body, which will give access to both outer

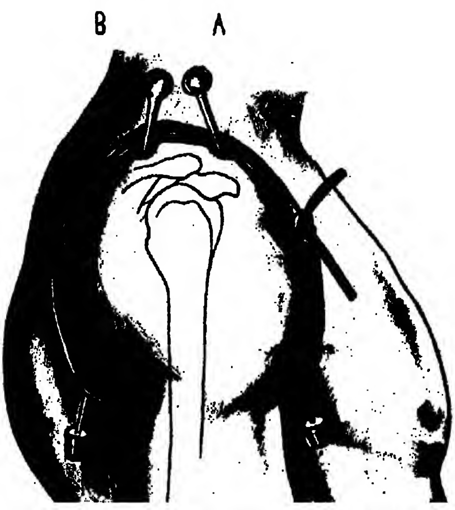


Fig. 347.—Wyeth's Pins Controlling Hemorrhage in Disarticulating at the Shoulder-joint.
A, Anterior pin; B, posterior pin. The rubber tubing is then wound about the limb, proximally to the pins, and knotted.

and inner aspects. The landmark is the surgical neck of the humerus (just below the tuberosities).

In making the incision, the base of the flap, which is U-shaped, is placed about 2.5 cm. (1 inch) below the saw-line through the surgical neck, its width being equal to half the circumference of the limb at the flap's upper limit, its length being that of the diameter at the saw-line. The anterior limb of the flap passes down the midanterior aspect of the arm, and the posterior limb down the midposterior aspect. The inner incision crosses the inner aspect of the arm, with a slight downward convexity, connecting the upper limits of the vertical limbs of the flap (Fig. 346, B).

The above incisions pass, at first, through the skin and fascia only. After the integuments have retracted, the external flap is cut from without inward, upon the line of the retracted tissues, beveling

obliquely upward and inward toward the upper limit of the flap. The bleeding vessels in this external wound are clamped as met. The inner incision is now deepened, and the axillary vessels tied as encountered and before being cut. The nerves are cut short. The tendon of the pectoralis major is preserved, the periosteum being divided below the bicipital groove and stripped up, including this tendon. Avoid opening the synovial sheath of the biceps tendon, dividing it low down, together with the coracobrachialis. Detach the tendons of the latissimus dorsi and teres major as subperiosteally as possible. Retract the outer flap and the parts on the inner aspect of the arm up to the saw-line, and divide the bone through the lowest part of the surgical neck possible. Avoid the circumflex nerve and the posterior circumflex artery. The brachial artery will have been tied in the

FIG. 348.—ILLUSTRATING THE USE OF SUTURES PASSED THROUGH THE TRUE SKIN AND TEMPORARILY TIED OVER RUBBER TUBING TO HOLD IT IN PLACE.
Used in order to control the vessels in disarticulating at the shoulder-joint in the absence of the Wyeth pins.

course of operation; branches of the anterior and posterior circumflex and muscular branches which have not been previously tied are now taken up. Bring the outer flap across the end of the bone, quilt the muscles of the flap to those divided in the inner incision, and suture the integumentary portion of the flap transversely to the corresponding tissues of the inner wound. Dress the arm against a full pad in the axilla.

Disarticulation at Shoulder-joint (*By Anterior Racket Method—Spence's Method*).—The queue of the incision is placed over the anterior aspect of the upper end of the humerus, the diverging limbs of the racket or oval encircling the inner and outer aspects of the arm and meeting behind.

The patient lies near the edge of the table, shoulders elevated, head to opposite side, limb partly abducted. The surgeon is on the outer

side of both shoulders, or he may stand on the inner side of the left. First assistant stands between the shoulder and patient's head, controlling hemorrhage and retracting flaps. Second assistant stands near the elbow, manipulating the limb.

The landmarks are the coracoid process and the pectorodeltoid groove.

Having abducted the arm and rotated the head of the humerus outward, begin the incision just to the outer side of the coracoid

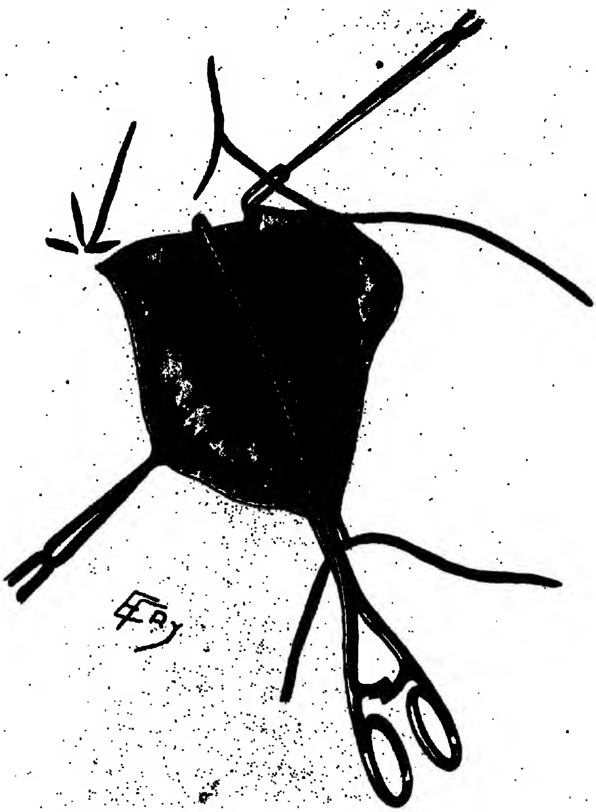


FIG. 349.—THOMAS' FORCEPS-TOURNIQUET FOR CONTROLLING HEMORRHAGE DURING OPERATIONS UPON THE EXTREMITIES.

The probe-pointed blade passes under the pectoral muscles and axillary vessels and nerves, and the serrated blade over these structures, the former coming out above the region of the previously divided clavicle. (Modified from Thomas.)

process, pass down through the clavicular fibers of the deltoid and pectoralis major, until the humeral attachment of the pectoralis major is reached, which is divided. From this point the outer limb of the racket curves gently outward through the lowest part of the deltoid to the posterior border of the axilla. From the point of division of the humeral attachment of the pectoralis major the inner limb of the racket curves downward across the inner aspect of the arm until it coincides with the opposite limb of the racket (Fig. 351, B).

The vertical portion of the incision is carried directly to the bone. The outer limb of the racket at first passes through skin and fascia, and is then deepened to the bone, through the periosteum, along the line of the incised integuments. The inner limb of the racket merely passes through the skin and fascia, and especial care is taken that it goes no deeper at this stage. Returning to the outer lip of the wound the anterior fibers of the deltoid will be found divided, and this lip of

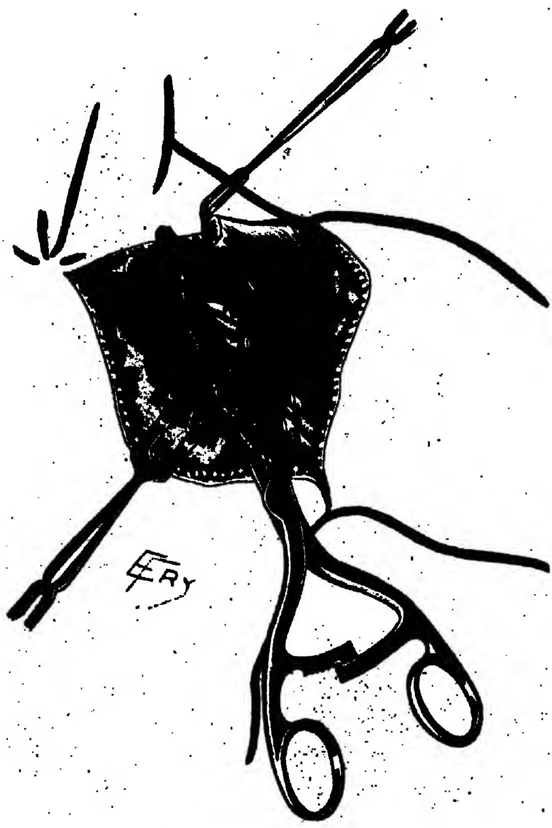


FIG. 350.—THOMAS' FORCEPS-TOURNIQUET.

The pectoral muscles and axillary structures have been divided distally to the clamp and turned forward. Note.—the probe-pointed blade is here erroneously shown to be where the serrated blade should be, and vice versâ. The correct position of the blades is shown in the preceding illustration. (Modified from Thomas.)

the wound is now freed from the bone and joint, as nearly subperiosteally as possible, thereby securing the retention of some of the attachments of the pectoralis major, latissimus dorsi, and teres major to the fibrous tissue, the freeing being accomplished by means of the thumb, periosteal elevator, and knife, and continuing up to the great tuberosity, carefully avoiding (by hugging the bone) injury to the circumflex nerve and posterior circumflex artery, which are raised from the bone in this outer flap. The inner flap is similarly, though

less extensively, freed up to the lesser tuberosity, carefully guarding the axillary vessels. By manipulating the limb from the elbow, flexed at a right angle, the head of the bone and its tuberosities are made to present themselves in the wound. By rotating inward the

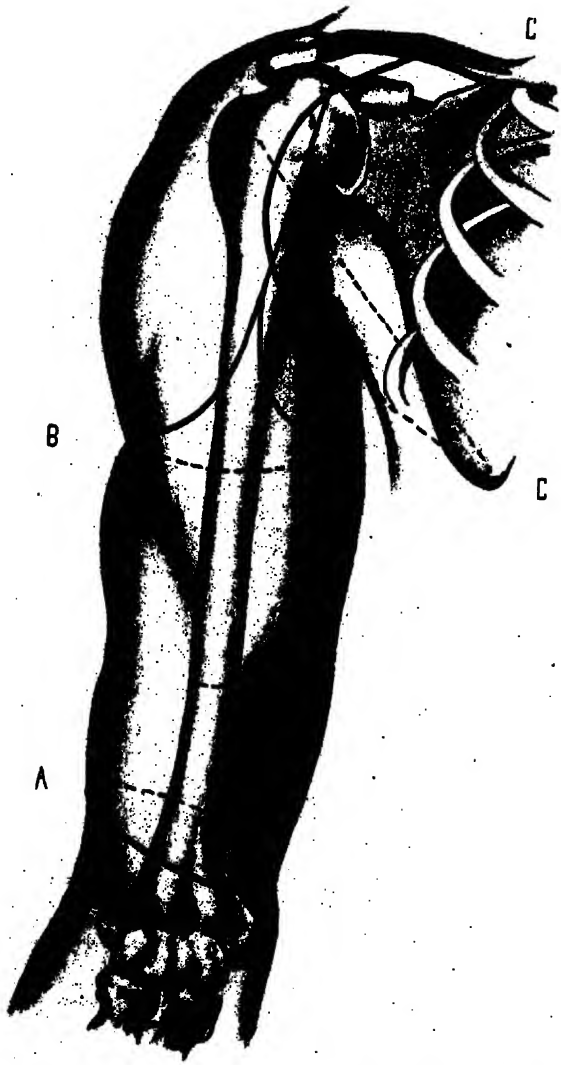


FIG. 351.—AMPUTATIONS THROUGH ARM AND AT SHOULDER.
A, Through lower arm, by oblique circular method; B, at shoulder, by anterior racket method (Spence's operation); C, of upper limb, together with scapula and part of clavicle, by antero-inferior (pectoro-axillary) and posterosuperior (cervicoscapular) flaps (Berger's operation).

great tuberosity presents, and the supraspinatus, infraspinatus, and teres minor are severed very close to the bone. By rotating outward the lesser tuberosity presents, and the subscapularis is severed. The long head of the biceps is next cut, and the capsule opened by dividing

it transversely against the head of the bone. The capsule being cut and the muscles attached to the tuberosities severed, the head of the bone is now disarticulated and thrust upward above the glenoid cavity, by abducting and rotating the head of the humerus outward, the connection of the limb being still maintained by the still unsevered tissues upon the inner aspect. The surgeon grasps the disarticulated head with the left hand and draws it outward from the trunk. As he does so the first assistant, standing behind the shoulder, places the palm of the fingers of both hands against the axillary aspect of the still uncut inner tissues, and his thumbs, one from each side, between the neck of the bone and the tissues of the inner side, compressing the axillary vessels between the thumbs as in the wound, and the outspread fingers in the axilla, until he feels all circulation controlled. The surgeon now passes a long knife between the neck of the bone and the thumb-nails of his assistant, and, by a steady, sawing movement, cuts his way from within downward and outward, aiming to come out on a line with the retracted integuments along the original incision, along the inner limb of the racket. As the knife cuts its way out, the fingers of the assistant follow the blade closely with the artery under his grasp. Just prior to the final emergence of the knife the tissues are tightly grasped and steadily held until the knife passes through the skin, when the assistant presents to the surgeon the cut margin of the inner lip, with the vessels in easy evidence. Tie the brachial artery at once, and the two brachial venæ comites and the basilic vein. In the vertical and external limb of the racket, in incising and deepening the wound, branches of the acromial, thoracic, the anterior circumflex, and muscular branches are first clamped, and then tied. The posterior circumflex nerve should not be injured. The nerves which are severed are to be cut short. The margins of the capsuloperiosteal wound, where an appreciable periosteum has been saved, are sutured. The muscles are quilted by deep and superficial buried absorbable sutures. Temporary drainage is provided. The integumentary edges of the wound are sutured in one vertical line. The stump should be snugly compressed against the thorax by the bandage.

Disarticulation at Shoulder-joint (*By External Racket Method—Larrey's Operation*).—The queue of the incision is placed over the external aspect of the upper end of the humerus, from the center of this incision (which first may have been made for exploration of the joint alone), the two limbs of the racket diverge, encircling the anterior and posterior aspects of the arm and meeting on the inner side.

The position is as in the operation just described.

The landmark is the prominence of the acromion.

The vertical incision, the arm being slightly abducted, begins immediately below the anterior aspect of the prominence of the acromion and passes thence vertically downward along the external aspect of the arm for 10 cm. (4 inches). From the center of the

vertical incision the two limbs of the oval or racket begin and pass obliquely downward over the anterior and posterior aspects of the limb, meeting upon its inner border on a level with the lowest part of the vertical incision (Fig. 345, C).

The vertical incision passes at once through the deltoid, directly to the bone and into the joint. The operation, which may have been begun as an exploratory one, may end with an investigation of the joint, or may proceed to an excision of the joint structures, or may end as an amputation. If the latter, the oval, or racket, incision, as above described, is added to the vertical incision. The limbs of the racket are, at first, incised through skin and fascia only, and may be made at one stroke, or, better, by two. The anterior limb of the racket is now deepened, while the arm is rotated outward, the incision passing through the anterior portion of the deltoid, the tendon of the pectoralis major is severed as near the bone as possible, the coraco-brachialis and biceps are divided, and, next to these, the axillary vessels are encountered, carefully exposed, and doubly ligated, beyond the posterior circumflex branch. This branch is then freed up to the joint. For the same reasons mentioned under the last operation the freeing of these flaps should be done as subperiosteally as possible. The posterior limb of the racket is similarly deepened, the arm being rotated inward, the incision passing through the posterior portion of the deltoid, and meeting the anterior limb upon the inner side of the arm. This flap is then also freed up to the joint as subperiosteally as possible. Disarticulation is accomplished (after severing close to the bone, in the above freeing of the anterior and posterior flap, the attachments of the supraspinatus, infraspinatus, teres minor to the great tuberosity, and the subscapularis to the lesser) by cutting the capsule and the long head of the biceps against the head of the bone transversely. The head of the bone is now disarticulated and thrust upward. To sever the remaining soft parts the surgeon grasps the disarticulated head of the humerus with his left hand and draws it outward, then inserts a long knife between the neck of the bone and the remaining undivided parts, and, by a sawing movement, cuts his way downward and outward between the severed axillary vessels and the bone, coming out on a line with the retracted inner limb of the racket incision (just as in the disarticulation by the anterior racket). Besides the above-named vessels, the anterior and posterior circumflex are both apt to be divided, as well as some muscular branches. The circumflex nerve is likely to be severed. All nerves are cut short. The capsule is to be trimmed if hanging in tags. Temporary drainage is used. The capsuloperiosteal or capsulomuscular covering is sutured, the muscles quilted deeply and superficially, and the skin sutured in a vertical line.

Amputation of Upper Limb, together with Scapula and Part of Clavicle *(By Antero-inferior (or Pectoro-axillary) and Posterosuperior (or Cervicoscapular) Flaps—Berger's Interscapulothoracic Operation).*— This operation consists in the removal of the upper limb, together

with the scapula and the outer two-thirds of the clavicle, en masse, without disarticulation at the shoulder-joint.

The various positions are given during the steps of the operation.

The landmarks are the outline of the clavicle, the outline of the scapula, and the line of the shoulder-joint articulation.

The operation consists of several distinct steps: (1) The subperiosteal excision of the middle third of the clavicle and the double ligature and division of the subclavian artery and vein: The patient lies upon the back, at the edge of the table, shoulders raised, and arm by side. Make an incision through the periosteum to the bone, over the upper surface of the clavicle, from the outer border of the sternomastoid to just beyond the acromioclavicular articulation (Fig. 351, C, C,). The vein from the cephalic to the external jugular is hereby cut and doubly ligated. The periosteum is raised, with curved periosteal elevator, from around the entire circumference of the middle third of the clavicle. A chain or Gigli saw is passed between the bone and periosteum, and the clavicle is divided at the junction of its inner and middle thirds. The outer two-thirds of the clavicle is now grasped with lion-jawed forceps and drawn outward, during which outward traction whatever periosteum remains is now detached from its middle third. The clavicle is then sawed at the junction of the middle and outer thirds by a chain, Gigli, or small saw. The middle third of the clavicle is thereby removed. The periosteum over the subclavius muscle and the subclavius muscle itself are now divided transversely, opposite the inner section of the clavicle, and are dissected up and turned outward, thereby exposing the subclavian vessels, surrounded by more or less fascia. Having divided the overlying fascia, the subclavian vein and then the artery are exposed. Both artery and vein are doubly ligated and divided opposite the lower border of the first rib, the former being secured first (to lessen the amount of blood left in the limb).

(2) The formation of the antero-inferior (or pectoro-axillary) flap: The patient lies on the back with the shoulder over the edge of the table, with arm abducted and head to the opposite side. The surgeon stands between the arm and trunk. The incision begins at the middle of the clavicular incision, curves downward and outward, passing close to the outer side of the coracoid process, thence along the anterior portion of the deltoid, just external to the pectorodeltoid groove, to the junction of the anterior axillary wall with the arm, thence across the lower border of the pectoralis major, thence transversely across the inner or axillary surface of the arm, to the lower border of the tendons of the latissimus dorsi and teres major. Here the limb is elevated, and the incision is carried downward and inward in the groove between the vertical border of the scapula and the muscular elevation formed by the teres major and the latissimus dorsi, to end over the posterior surface of the inferior angle of the scapula. This incision passes, at first, through skin and fascia, and is then deepened through the pectoral and axillary tissues, the pectoralis major being cut where its tendinous

portion commences, the pectoralis minor near the coracoid process, the brachial plexus near the first rib, the latissimus dorsi in the more posterior part of the line of incision, and whatever remaining axillary tissues bind the limb are cut as encountered. The shoulder is thus freed from the trunk anteriorly and tends to fall outward and backward.

(3) The formation of the posterosuperior (or cervicoscapular) flap: The patient is still supine, with the shoulder over the edge of the table; the arm is now drawn across the chest to emphasize the scapular region. The surgeon stands to the outer side. The incision begins at the outer end of the clavicular incision, just external to the acromioclavicular joint, passing thence backward over the spine of the scapula by the shortest route, to join the lower end of the antero-inferior flap incision over the inferior angle of the scapula. This incision at first involves only the skin and fascia, which are then well retracted along their upper part, thus exposing the trapezius, which is now divided near its attachment to the clavicle and scapula, and thus severed from the whole limb.

(4) The severing of connections of scapula to trunk: The patient lies as in the last step, and the surgeon stands to the inner side of the right and outer side of the left limb. The anterior and posterior flaps are well retracted, and the limb permitted to hang away from the side. The superior and vertical borders of the scapula are rendered prominent, and are now freed by cutting the following muscles close to the bone, in order from above downward; the omohyoid, levator anguli scapulæ, rhomboideus minor, rhomboideus major, and serratus magnus. The upper extremity is now freed from the trunk, the muscles arising from the scapula, and inserted into the humerus (teres major and minor, subscapularis, supraspinatus, and infraspinatus), are removed untouched with the limb.

(5) Control of hemorrhage: The preliminary ligation of the subclavian artery and vein controls the chief hemorrhage. In forming the anterior flap branches of the acromiothoracic, long thoracic, and subscapular are encountered. In forming the posterior flap the muscular branches in the trapezius are met. In severing the scapula the chief bleeding occurs, the suprascapular artery is to be tied near the omohyoid, as it is about to enter the supraspinatus fossa, and the posterior scapular is to be tied near the upper angle of the scapula, just after dividing the levator anguli scapulæ.

(6) The closure of the wound: All the nerves are divided short. Generally, no sufficient redundancy of muscle is present to admit of quilting, it usually being difficult to approximate the edges of the wound, but, if it be possible, quilting of the muscles together with buried gut sutures should be done, to make a thicker stump-padding and to take the strain off the cutaneous sutures. The anterior and posterior flaps are brought together and sutured in one oblique line, extending from above downward, outward, and backward. To obliviate the dead spaces which tend to form in so extensive a wound,

considerable even pressure is applied in the dressings which bind the parts to the thorax. No drainage is indicated in simple cases.

Amputation through Last Phalanx of Toes (*By Plantar Flap*).—This operation is hardly feasible as a definite procedure, which amounts generally to a trimming of the parts, except in the case of the great toe, which is the operation here described.

The position for all amputations about the toes is the following: The patient is supine, with the foot beyond the end of the table, the

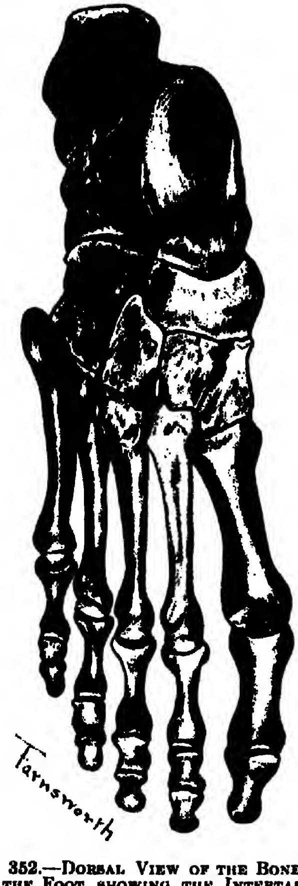


FIG. 352.—DORSAL VIEW OF THE BONES OF THE FOOT, SHOWING THE INTERTARSAL, TARSOMETATARSAL, AND INTERMETATARSAL ARTICULATIONS.

FIG. 353.—PLANTAR VIEW OF THE BONES OF THE FOOT, SHOWING THE INTERTARSAL, TARSOMETATARSAL, AND INTERMETATARSAL ARTICULATIONS.

toe extended during plantar incisions, and flexed during dorsal incisions. The assistant stands in front of the surgeon, steadying the foot with both hands, the fingers of which, at the same time, draw aside and out of the way the adjacent toes. The surgeon grasps the toe to be removed with the thumb and forefinger of the left hand, with his thumb on the dorsum of the toe during the dorsal incisions, and on the plantar surface of the toe during the plantar incisions, the index-finger occupying the

opposite aspect in each case. His hand will be supinated during the dorsal and pronated during the plantar incisions.

The landmark is the saw-line, which will lie between the base of the nail and the interphalangeal joint above.

The vertical portion of the incision begins opposite the saw-line, in the midlateral aspect of the toe, or a little nearer the dorsum (which furnishes a fuller plantar flap), passes straight down that aspect and around the pulp of the toe to the corresponding point on the opposite side. The transverse dorsal incision connects the upper ends of the limbs, with slight downward convexity (Fig. 359, A).

Having incised skin and fascia, these incisions are deepened to the bone, the soft parts are separated up to the saw-line and retracted. The tip of the phalanx is grasped with bone-holding forceps and steadied while the bone is sawed. If the base of the last phalanx be left, the insertion of the extensor and flexor tendons will be preserved. Arteries rarely have to be tied, except in the case of the great toe.

Disarticulation at Second Interphalangeal Joint of Toes *(By Plantar Flap)*.—A U-shaped flap is raised from the plantar aspect of the toe and approximated to the dorsal wound.

The position is the same as for the amputation of the last phalanx (p. 837). The landmark is the second interphalangeal joint-line.

The vertical portion of the incision begins opposite the joint-line, in the midlateral aspect or a little nearer the dorsum, passes directly down this aspect of the toe a distance sufficient to furnish one and one-half diameters of the toe at the saw-line, then rounds bluntly across the plantar surface, and is continued up to a corresponding point on the opposite side. The transverse incision connects the upper limbs of the flap by a slightly rounded convex line (Fig. 359, A).

Deepen the vertical portion and the rounded end of the flap to the bone, dissect up the soft parts to the joint-line, cutting the glenoid ligament and flexor tendon against the base of the last phalanx, thus opening the joint. Forcibly flex the joint and deepen the transverse incision to and into the joint, entering from the dorsum and cutting the lateral ligaments from within outward. Two dorsal and two plantar digital arteries may require ligation. Close the flexor sheath with catgut, and, in the great toe, include the flexor tendon. Suture the plantar flap to the transverse dorsal wound.

Amputation through Second Phalanx of Toes *(By Plantar Flap)*.—The manner of performing this operation is sufficiently described in the amputation through the last phalanx (p. 837), and the dimensions of the flap, under the disarticulation at the second interphalangeal joint (above).

Disarticulation at First Interphalangeal Joints of Toes *(By Oval Method)*.—The queue of the incision is over the dorsal aspect of the joint, the limbs of the oval encircling the toe beyond the first interphalangeal joint-line.

The position is the same as in amputating through the last phalanx. The landmark is the first interphalangeal joint.

The queue of the oval begins just above the head of the first phalanx, on its middorsal aspect, passes vertically downward over the head of the phalanx, and continues down to near the middle of the first phalanx, where the two corresponding limbs diverge to encircle the second phalanx and meet in the middle of its plantar aspect (Fig. 354, C).

Deepen the dorsal incision to the extensor tendon. Extend the toe and deepen the oval to the bone, cutting the flexor tendons transversely. Dissect up the soft parts upon the flexor and lateral aspects. Divide the glenoid (anterior) ligament by cutting against the base of the second phalanx and opening the joint. Divide the lateral ligaments from within outward. Draw upon the toe and cut the extensor tendon high up. Two plantar and two dorsal digital arteries are cut—the former may require ligation. Close the flexor sheath. Suture the wound vertically. The cicatrix will be vertical and dorsoterminal.

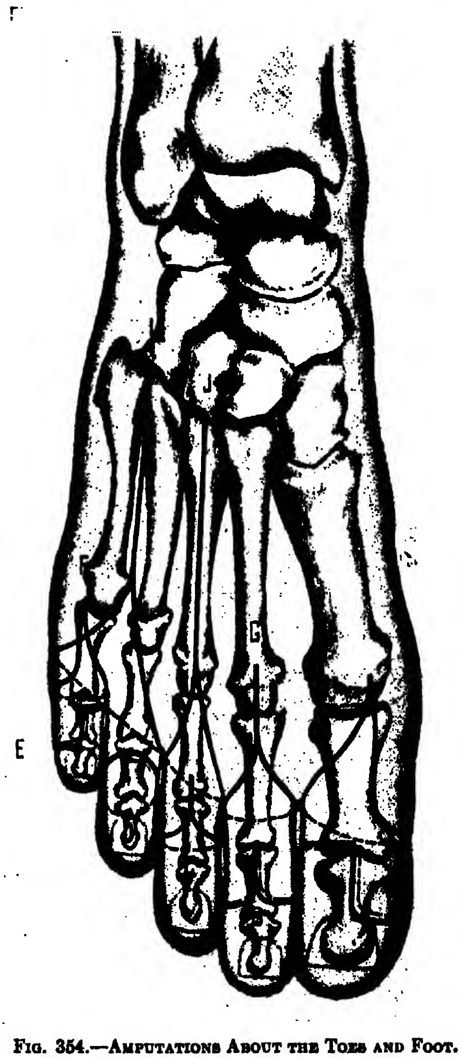


FIG. 354.—AMPUTATIONS ABOUT THE TOES AND FOOT.

A, At interphalangeal joint of great toe, by a single internal flap; B, at first phalangeal joint, by equal lateral flaps; C, at first phalangeal joint, by oval method; D, through second phalanx, by oblique circular; E, at first phalangeal joint of little toe, by single external flap; F, at metatarsophalangeal joint of little toe, by externodorsal flap; G, at metatarsophalangeal joint, by oval method; H, at metatarsophalangeal joint of great toe, by internoplantar flap; I, of two inner toes at tarsometatarsal joints, by racket method; J, of toe, with its entire metatarsal at tarsometatarsal joint, by racket method.

Amputation through First Phalanx of Toes (*By Oval Method*).—The operation is exactly similar to that for disarticulation at the first interphalangeal joint, just described, except that the queue begins just above the future saw-line, and the oval extends down the toe a distance that will make the covering furnished by the two lateral aspects of the oval about equal to one and one-half diameters of the toe at the saw-line.

Disarticulation of Toes, in General, at Metatarsophalangeal Joints (*By Oval Method*).—The operation is the same, in principle, as disarticulation at the first interphalangeal joint by the oval method.

The position is as for the toes in general (p. 837). The landmark is the metatarsophalangeal joint.

The queue of the incision begins just above the head of the metatarsal, over its middorsal aspect, passes downward in the median line until past the base of the first phalanx, the limbs of the oval now gradually diverge to pass obliquely downward over the lateral aspects of the toes and cross the plantar surface transversely, meeting just in front of the line of the webs (Fig. 354, G).

The vertical portion of the incision is deepened to the extensor tendon, the lateral portions are cut to the bone, the toe is extended, and the plantar aspect cut transversely to the bone, thereby severing the flexor tendons high up. The soft parts are freed, partly by retraction and partly by dissection, from the upper portion of the first phalanx to the joint-line, which lies about 2.5 cm. (1 inch) above the web. The glenoid ligament is cut transversely against the base of the first phalanx and the joint opened. Disarticulation may be completed from below, but more conveniently by severing the extensor tendon and disarticulating from the dorsum, cutting the lateral ligament from within outward as the toe is rotated from side to side. Two dorsal and two plantar digital arteries are cut. The flexor sheath should be closed. The wound is sutured vertically, the scar becoming dorso-terminal.

Disarticulation of Great Toe at Metatarsophalangeal Joint (*By Internoplantar Flap—Farabeuf*).—The operation is a modification of the oval method, whereby the covering is gotten from the internal and plantar aspects of the great toe, and the cicatrix is brought well over to lie obliquely from the upper angle of the interdigital web to the head of the metatarsal, and thus well removed from internal and terminal pressure.

The position is as for amputating through the toes in general (p. 837). The landmarks are the metatarsophalangeal joint-line and the interdigital web.

The incision begins over the metatarsophalangeal joint, at the junction of the dorsal and internal surfaces, passes vertically down the toe in the line represented by the junction of these two surfaces (parallel with the extensor tendon), nearly to the head of the first phalanx, curves thence downward over the inner surface to the junction of the internal and plantar surfaces, passes thence obliquely across the plantar surface to the angle of the interdigital web, thence runs directly over the external and dorsal surfaces of the toe to the point of beginning by the shortest route (Fig. 354, H).

This incision is now deepened to the bone in the same order as made, extending the toe while cutting the plantar and flexing it while cutting the dorsal tissues. Free the soft parts up to the joint-line. Sever the

glenoid ligament against the base of the first phalanx, thus opening the joint, and leaving the ligament and the sesamoid bones in the stump. Divide the lateral ligaments and the extensor tendon. Two plantar and two dorsal digital arteries are cut and will probably require ligation. Close the flexor sheath. Include the cut flexor and extensor tendons in the tissues of the stump. Suture the internal and plantar portions of the oval to the straight incision from the interdigital web to the head of the metatarsal, which will represent the line of cicatrix.

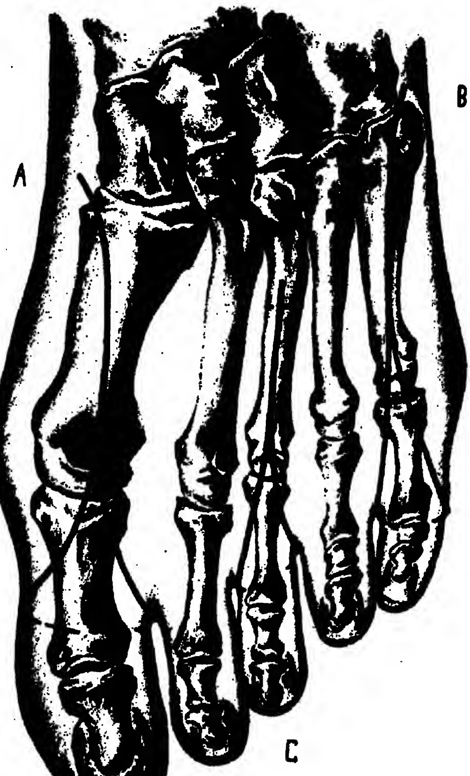


FIG. 355.—AMPUTATIONS ABOUT THE FOOT.

A, Disarticulation of the great toe at the tarsometatarsal joint by a curvilinear racket incision; B, disarticulation of the little toe at the tarsometatarsal joint by a curvilinear racket incision; C, amputation of a toe with part of its metatarsal by a racket incision.

Disarticulation of Little Toe at Metatarsophalangeal Joint *(By Externodorsal Flap—Farabeuf)*.—This is the reverse of the last operation, a modification of the oval method, whereby the covering is gotten from the external and dorsal aspects of the little toe, and the cicatrix brought well over to lie obliquely from the upper angle of the interdigital web to the head of the metatarsal, and thus well removed from external and terminal pressure. The landmark is the same as in the last operation.

The incision begins over the dorsal aspect of the metatarsophalangeal joint, just to the inner side of the extensor tendon, passes vertically down the inner margin of the tendon to the end of the first phalanx, curves thence downward and outward over the external aspect of the toe, thence obliquely across the plantar surface to the angle of the interdigital web, thence along the internal aspect of the toe to the point of beginning, by the shortest route (Fig. 354, F).

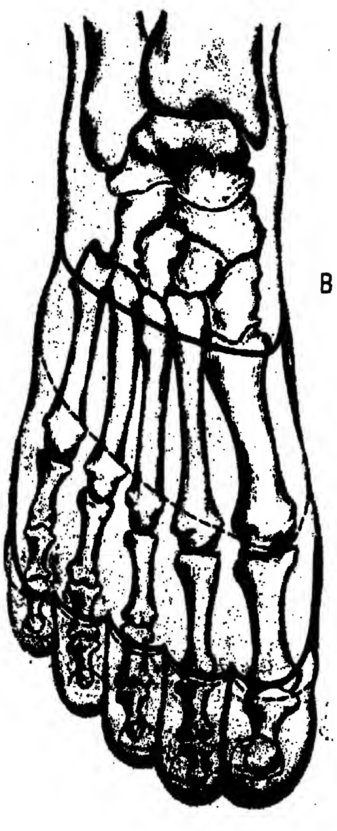


FIG. 356.—DISARTICULATIONS ABOUT THE FOOT. A, A, Of all the toes at metatarsophalangeal joints, by equal short dorsal and plantar flaps; B, B, of all the toes at tarsometatarsal joints, by short dorsal and long plantar flaps (Lisfranc's operation).

The steps of the operation are exactly similar to those of the disarticulation of the metatarsophalangeal joint of the great toe. The dorsal, external, and part of the plantar portion of the oval are sutured to the straight incision from the metatarsophalangeal joint to the interdigital web, which will represent the line of cicatrix and be out of the way of pressure.

Disarticulation of Two Adjoining Toes at Metatarsophalangeal Joint (*By Oval Method*).—The operation is the same as the disarticulation of a single toe at the metatarsophalangeal joint (p. 840), except that the queue of the oval is placed between the two toes, beginning a little higher above the metatarsophalangeal joint-line, the two limbs of the oval diverging to encircle the outer and inner toes and meet at the margin of the web between the toes. Each toe is then freed up to the metatarsophalangeal joint and disarticulated. The wound is sutured as a vertical cicatrix.

Disarticulation of all Toes, en Masse, at Metatarsophalangeal Joints (*By Equal Short Dorsal and Plantar Flaps*).—The covering is gotten equally from the dorsal and plantar surfaces, and the scar is terminal (Fig. 357, A, A).

The patient is supine, the foot over the edge of the table. The surgeon grasps the toes with the left hand, with the thumb on the dorsum and the fingers on the plantar surface for dorsal incisions,

and the thumb on the plantar and the fingers on the dorsum for the plantar incisions, manipulating the foot as indicated. After the incisions are made, an assistant takes the toes and the surgeon manipulates the flap. The surgeon stands for the dorsal and sits for the plantar incisions.

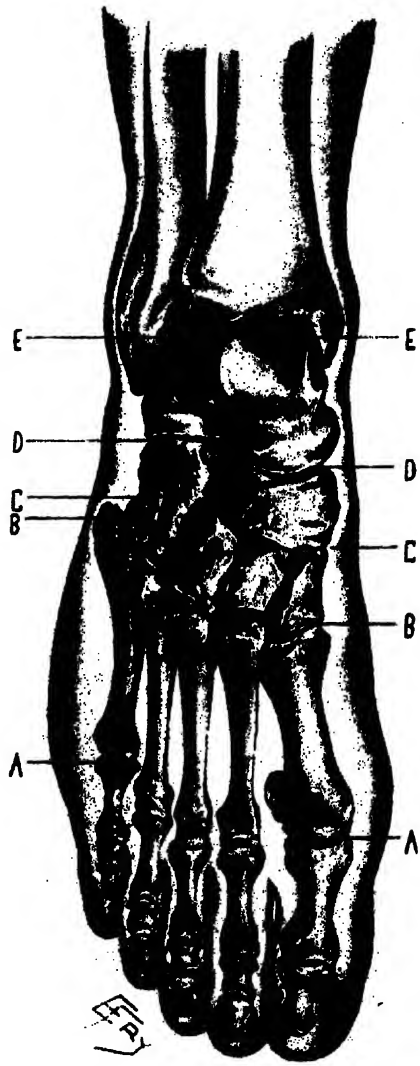


Fig. 357.—Lines of Disarticulations About the Foot.

A, A, Metatarsophalangeal disarticulation; B, B, tarsometatarsal disarticulation (Lisfranc's operation); C, C, anterior intertarsal amputation (between the cuneiforms and scaphoid, with transverse section of the cuboid—the Jaeger-Bona or Forbes' operation); D, D, posterior intertarsal or mediotarsal disarticulation (Chopart's operation); E, E, disarticulation at the ankle-joint.

Note.—Pirogoff's intercalcaneal osteoplastic amputation, with section of the tibia and fibula, and also the subastragaloid disarticulation are not shown here.

Supposing the left foot to be operated upon, the dorsal incision (with foot extended and toes flexed) begins at the midlateral aspect of the metatarsophalangeal joint of the great toe, passes vertically down the inner margin of the foot to the middle of the first phalanx, thence rounds broadly on to the dorsum of the foot, and follows the line of the web, dipping in between the toes as they are separated, until the little toe is reached, when the incision rounds broadly into the outer aspect of the foot and passes vertically up in the midlateral aspect to the metatarsophalangeal joint. The plantar incision (with foot flexed and toes extended) passes transversely across the plantar surface of the foot, connecting the distal end of the vertical limbs of the dorsal incision, beginning at a point where the vertical limb begins to round on to the dorsum, the plantar incision rounds on to the plantar surface at the middle of the first phalanx of the great toe, and thence follows the line of the web and the creases of the toes, dipping in between the toes as they are separated until the little toe is reached, when the incision rounds on to the outer aspect

and joins the dorsal incision at a point where the outer vertical limb begins to round on to the dorsum (Fig. 356, A, A).

The dorsal incision is deepened to the extensor tendons and freed half-way back to the joint-line, when the extensor tendons are cut transversely, each toe being previously forcibly flexed in turn. The flap of the entire soft parts is then dissected back to the metatarsophalangeal joint-line. The plantar incision is now deepened to the flexor tendons, and freed half-way back to the joint-line, when the flexor tendons are cut transversely, each toe being previously forcibly extended in turn. The flap of the entire soft parts is then dissected back to the metatarsophalangeal joint-line. Both flaps are then well retracted to the general joint-line, the toes are flexed, and the joints are opened from the dorsum, and the lateral ligaments cut from within outward. The toes are then extended and the plantar ligaments are cut from the plantar surface, preserving the glenoid ligaments. The disarticulation of each toe is thus completed in turn. The flexor sheaths are closed. Two plantar and two dorsal digital arteries for each toe are cut; the latter may not require ligature. The dorsal and plantar flaps are sutured in one lateroterminal line.

FIG. 358.—AMPUTATIONS ABOUT THE FOOT.
A, A, Amputation of all the toes through the metatarsus, by short dorsal and long plantar flaps (metatarsal amputation); B, B, disarticulation of anterior part of foot at mediotarsal joints, by short dorsal and long plantar flaps (Chopart's operation).

Amputation of Toes, in General, with Part of their Metatarsals (*By Racket Method*).—The amputation of the toes with a part of their metatarsals is so similar, in all essential details, to disarticulation with their entire metatarsals, that the former will not be separately given (as was done in the case of the fingers). The best method of removing any of the toes with a part of their metatarsals, whether an inside toe or the great or little toe, is by the racket method (p. 485). The best method for the removal of two or three contiguous toes, with parts of their metatarsals, is by the oval operation (p. 840).

The practical differences between the partial and complete opera-

tions are that the incision begins, in the former, just above the saw-line, instead of just above the tarsometatarsal joint-line, and, instead of disarticulating the proximal end of the bone, it is sawed with a Gigli or chain saw (Fig. 354, I, and Fig. 355, C).

All of the toes with parts of their metatarsals through the metatarsus by a short dorsal and long plantar flap constituting the metatarsal amputation (Fig. 358, A, A).

Disarticulation of Toes, in General, with their Entire Metatarsals (*By Racket Method*).—The coverings are gotten from the lateral and plantar aspects, and the cicatrix is vertical and dorso-terminal.

The patient is supine, with the foot over the edge of the table. The surgeon is opposite the foot, standing while operating on the dorsum, sitting while working on the plantar aspect, steadying the toes with his left fingers during the incisions, while the assistant holds the ankle. The landmarks are the tarsometatarsal joint and the interdigital web.

The incision begins just above the tarsometatarsal joint, in the middorsal aspect, passes vertically down in the median line to the head of the metatarsal, thence the two limbs of the oval diverge, the outer limb running downward across the outer aspect of the toe to the web, the inner limb across the inner aspect to the web, the two meeting in the digitoplantar crease (which about corresponds to the center of the first phalanx) (Fig. 354, J).

Deepen the vertical incision, dividing the extensor tendons as high up as encountered, while the toe is flexed. Deepen the oval incision to the bone, upon the lateral and plantar aspects, extending the toes while severing the flexor tendons transversely. Free the soft parts along the dorsum and lateral surfaces with a periosteal elevator, hugging the bone closely. Forcibly extend the toe and its metatarsal and free the plantar surface as far as possible. Sever from the dorsum the ligaments binding the metatarsus to the tarsus and to the adjacent metatarsals, while the toe is being manipulated and the ligaments are put upon the stretch, thus completing the disarticulation. Divide the flexor tendons high up and close the sheaths. Two dorsal and two plantar digital arteries are to be tied. Suture the wound in one vertical line.

Disarticulation of Great Toe with its Entire Metatarsal (*By Racket Method*).—The description and the landmarks of the operation are the same as those of the last procedure.

The incision begins just above the tarsometatarsal joint, at its dorso-internal aspect, passes vertically downward along the outer margin of the extensor tendon to just beyond the center of the metatarsal, thence the two limbs of the oval diverge, the outer limb passing across the dorso-external aspect of the toe to the web, the inner limb passing across the dorso-internal aspect to the plantar surface, at a point opposite the web, the two limbs meeting in the digitoplantar crease. If needed for purpose of exposing the joint more readily, an additional transverse incision may be added to the upper end of the

vertical incision, running as far as thought necessary directly inward parallel with the tarsometatarsal joint (Figs. 355, A, and 359, B).

Deepen the vertical incision, exposing and dividing the tendons of the extensor proprius and brevis hallucis near the tarsometatarsal joint. Deepen the limbs of the oval, cutting to the bone along the lateral and plantar surfaces. Free, up to the tarsometatarsal, the soft parts from the external, internal, and plantar surfaces of the metatarsal and phalanx, by closely hugging the bones with periosteal elevator, rotating the toe as indicated. The sesamoid bones are left behind, and the structures about the metatarsophalangeal joint are removed as

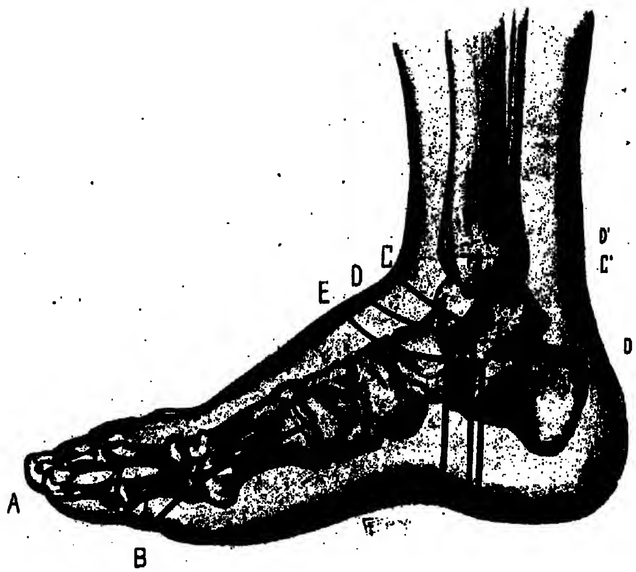


FIG. 359.—AMPUTATIONS ABOUT THE TOES AND FOOT. (Inner view.)

A, At interphalangeal joint of great toe, by plantar flap; B, of great toe and its metatarsal, at tarsometatarsal joint, by racket method, with transverse incision added to upper end; C, inner aspect of plantar and dorsal incisions in Syme's disarticulation of foot at ankle, by heel-flap; C′, line of tibial and fibular section; D, inner aspect of plantar and dorsal incisions, in Pirogoff's disarticulation at ankle, by heel-flap; D′, line of section of bones of leg, in same; D″, line of section of os calcis, in same; E, inner aspect of plantar and dorsal incisions in subastragaloid disarticulation of foot, by heel-flap.

nearly subcapsuloperiosteally as possible, in order to retain the attachment of the severed tendons there inserted. Open the tarsometatarsal joint from the dorsum, completing the disarticulation by severing the remaining ligaments while under tension during the manipulation of the toe. Divide the tendons of the peroneus longus and tibialis anticus. Cut the tendons short and close their sheaths. The following arteries are divided: two dorsal digital, two plantar digital, and the termination of the internal plantar. Guard against wounding the communicating branch of the dorsalis pedis in the first interosseous space. The suture line will be vertical, and fall over the dorso-external aspect of the toe, out of the way of pressure.

Disarticulation of Little Toe with its Entire Metatarsal *(By Racket Incision)*.—The description and landmarks are as in the last operation.

The incision begins just above the tarsometatarsal joint at its dorso-external aspect, passes vertically downward along the outer margin of the extensor tendon to just beyond the center of the metatarsal, thence the two limbs of the oval diverge, the inner limb passing across the dorso-internal aspect of the toe to the web, the outer limb passing across the dorso-external aspect of the plantar surface at a point opposite the web, the two limbs meeting in the digitoplantar

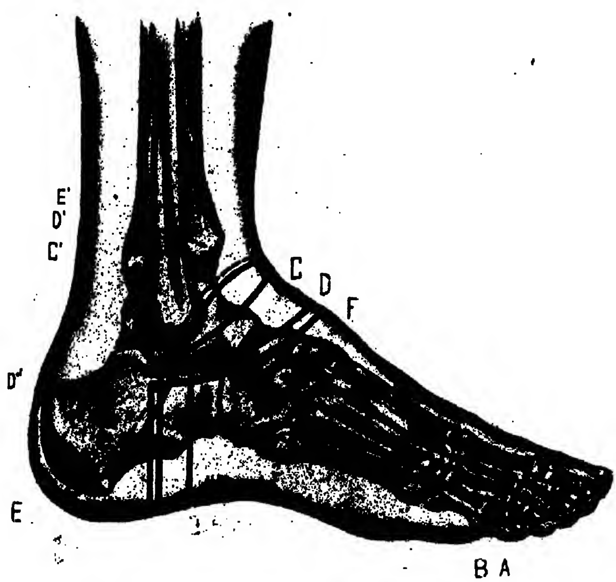


Fig. 360.—Amputations About the Toes and Foot. (Outer view.)

A, Through first interphalangeal joint of little toe, by oblique circular method; B, of little toe and its metatarsal, by racket method, with added curved incision at upper end; C, outer aspect of plantar and dorsal incisions, in Syme's disarticulation of foot at ankle, by a heel-flap; C′, line of section through tibia and fibula, in same; D, outer aspect of plantar and dorsal incisions, in Pirogoff's disarticulation at ankle; D′, line of section of tibia and fibula in same; D″, line of section of os calcis, in same; E, supramalleolar amputation of leg, by oblique elliptical incision; E′, tibial and fibular section in same; F, outer aspect of dorsal and plantar incisions in subastragaloid disarticulation of foot by heel-flap.

groove. If needed for the purpose of more readily exposing the joint, an additional transverse or oblique incision may be added to the upper end of the vertical incision, by prolonging the latter a short way directly outward parallel with the tarsometatarsal joint, or the upper end of the straight incision may be given a slight outward curve (Figs. 355, B, and 360, B).

The steps of the operation are practically the same as in the corresponding operation upon the great toe (p. 845). The metatarsal is disarticulated from the cuboid and from the fourth metatarsal. Two dorsal and two plantar digital arteries are cut.

Disarticulation of Two or Three Contiguous Toes with their Entire Metatarsals (*By Oval or Racket Method*).—The procedure is the same, in principle, as the operation for the removal of a single toe and its metatarsal (p. 845). Where two contiguous toes are removed, the vertical portion of the incision is placed between the toes, beginning just above the saw-line and diverging to include both toes, meeting on the plantar surface of the web between them. Where three contiguous toes are removed, the vertical portion of the incision is placed over the middle metatarsal, beginning at the disarticulation-line, or just above, and diverging to include all three toes, meeting at the center of the plantar surface of the middle toe in the digitoplantar crease (Fig. 354, I).

Disarticulation of all the Toes at the Tarsometatarsal Joints (*By Short Dorsal and Long Plantar Flaps—Lisfranc's Operation*).—The operation consists of the disarticulation of the anterior portion of the foot at the tarsometatarsal line, the stump being formed of plantar and dorsal tissues (Fig. 357, B, B).

The patient is supine, with the foot over the edge of the table. The surgeon is opposite the foot, standing while operating on the dorsum, and sitting while working upon the plantar aspect, steadying the toes with his left fingers during the incisions, while the assistant holds the ankle, and as soon as the incisions are made, the assistant takes the toes, while the surgeon grasps the flaps with his left hand.

The landmarks are the tarsometatarsal joint-lines and the heads of the metatarsals (Figs. 352 and 353).

Supposing the foot of the right side to be operated upon, the dorsal flap is outlined in the following way: the surgeon's left hand grasps the foot with his thumb on the base of the fifth metatarsal and his forefinger on the base of the first, his palm to the sole, the foot being extended. The incision begins just behind the base of the fifth metatarsal, nearer the plantar than the dorsal surface, passes straight down the outer aspect of the foot for 2.5 cm. (1 inch), thence rounds on to the dorsum and crosses the foot with slight downward convexity, parallel with and about 1.3 cm. (½ inch) below the tarsometatarsal joints, reaching the inner border of the foot, 1.3 cm. (½ inch) below the tarsometatarsal joint, thence rounds into the inner aspect of the foot and passes straight upward and ends 2 cm. (¾ inch) above the cuneiform metatarsal articulation of the great toe, somewhat nearer the plantar than the dorsal aspect. The plantar flap is now made, the surgeon holds the toes between the fingers on the dorsum and thumb on the plantar surfaces, the foot being flexed. The incision is continuous with the horizontal portion of the dorsal incision, passing down the outer lateral aspect of the foot along the plantar edge of the fifth metatarsal to just below its middle, then rounds into the sole and sweeps obliquely across the plantar surface in such a way as to cross the fifth metatarsal just above its neck, the fourth metatarsal at its neck, the third and second opposite their heads, and the first metatarsal at the metatarsophalangeal joint, thence rounds into the inner

midlateral aspect of the foot, and passes straight up its border along the plantar edge of the first metatarsal, to become continuous with the vertical portion of the dorsal incision (Fig. 356, B, B).

Deepen the dorsal line to the extensor tendons and free back the superficial tissues for about 6 mm. (¼ inch), and then divide all the soft parts down to the bones, while the foot is fully extended on the leg and the toes flexed on the foot, and free the flap to, and very slightly above, the joint-line, hugging the bone to save the interosseous vessels and portion of interosseous muscles. Deepen the plantar incision to the flexor tendons and free back the flap of superficial tissues to the hollow behind the heads of the metatarsals, and then divide all the soft parts down to the bones, while the foot is fully flexed on the leg and the toes extended on the foot, and free the flap to, and very slightly above, the tarsometatarsal joint-line. Both flaps contain all the soft parts to the bones. Disarticulation is now accomplished from the dorsum. Retract the flaps, extend the foot, and begin the disarticulation by entering the knife behind the prominent base of the fifth metatarsal at the outer side of the foot, and then, passing obliquely forward and inward, cut the peroneus brevis and tertius tendon and disarticulate the fifth, fourth, and third metatarsal. Then turn to the inner side of the foot, and sever the ligaments of the first tarsometatarsal joint and divide the expansion of the tibialis anticus. There remains the freeing of the second metatarsal, which is somewhat difficult unless undertaken in a definite manner (Figs. 352 and 353). Hold the knife like a dagger, with the cutting edge toward the ankle, the blade pointing forward at an angle with the dorsum of the foot, enter the point deeply between the bases of the first and second metatarsals, where they begin to bind; elevate the handle until perpendicular to the dorsum, cutting, at the same time, forward, and thus the ligaments binding the base of the second metatarsal to the base of the first metatarsal and internal cuneiform are severed, the manœuver being called the "coup de maitre." Repeat this manœuver between the bases of the second and third metatarsals. Complete the disarticulation of the second metatarsal by severing, from the dorsum, the ligaments between the middle cuneiform and the base of the metatarsal. Divide any connecting bands upon the plantar aspects of the joints. The peroneus longus tendon now alone holds the metatarsus; put this upon the stretch, dividing it high up. The following arteries are to be tied: In the dorsal flap, four dorsal interosseous; communicating branch of dorsalis pedis; in the plantar flap, five plantar digital branches of external plantar (and possibly the external plantar itself), and the termination of the internal plantar. Suture any open sheaths. Quilt the muscles. Suture the plantar and dorsal flaps in one transverse line. Support the stump upon a splint.

Disarticulation of Anterior Part of Foot at Mediotarsal Joint *(By Short Dorsal and Long Plantar Flaps—Chopart's Operation)*.—This operation consists of the disarticulation of the anterior portion of the foot at the astragaloscaphoid and calcaneocuboid joints, by means

of a short dorsal and long plantar flap, the operation being somewhat similar to Lisfranc's tarsometatarsal disarticulation (Fig. 357, D, D). The position is as in Lisfranc's operation (p. 848).

The landmarks are the astragaloscaphoid joint (just behind the tuberosity of the scaphoid); the calcaneocuboid joint (midway between the external malleolus and the tubercle of the fifth metatarsal); the tarsometatarsal joint-line, and the middle of the metatarsus.

Supposing the right foot to be the one operated upon, the plantar incision begins on the outer aspect of the foot, a little nearer the plantar than the dorsal surface, and at a point opposite the calcaneocuboid joint (see landmarks), passes straight down the outer side of the foot to near the middle of the fifth metatarsal, thence rounds inward and crosses the sole of the foot, opposite the middle of the metatarsals, to the inner side of the foot, rounds into the inner border of the foot, and passes straight up that border a little nearer the plantar than the dorsal surface, to a point opposite the astragaloscaphoid joint (see landmarks). The dorsal incision begins by curving from the outer limb of the plantar incision, just posterior to the fifth tarsometatarsal joint, and ends by curving into the inner limb of the plantar incision, just posterior to the first tarsometatarsal joint, crossing the dorsum opposite the bases of the metatarsals (Fig. 358, B, B).

Deepen the plantar incision, the foot flexed on the leg and the toes extended on the foot, to the flexor tendons. Free the skin and fascia a short distance, divide all soft parts to the bone, and dissect up the flap of the entire soft parts to the mediotarsal joint. Deepen the dorsal incision, the foot extended on the leg and the toes flexed on the foot, to the extensor tendons. Free the skin and fascia a short distance, divide all the soft parts to the bones, and dissect up the flap of the entire soft tissues to the mediotarsal joint. Disarticulate from the dorsum while the foot is forcibly extended, rotating the forepart of the foot outward while severing the ligaments of the astragaloscaphoid joint, and inward while dividing those of the calcaneocuboid articulation. The tendons of the tibialis anticus and posticus and peroneus tertius, brevis, and longus are cut among the deeper structures. Quilt the muscular and tendinous tissues of the two flaps, especially suturing the extensor tendons and tibialis anticus of the dorsal flap, to the tissues of the plantar flap, in order to counteract the tendency of the tendo Achillis permanently to extend the foot. In the dorsal flap the dorsalis pedis and its tarsal and metatarsal branches are cut, and in the plantar flap the terminations of the external and internal plantar arteries and plantar digital branches.

Disarticulation of Foot at Astragaloscaphoid and Astragalocalcaneal Joints—Subastragaloid Disarticulation (*By Large Internoplantar Flap—Farabeuf*).—The procedure is a modified oval method. The structures below the astragalus are removed, the stump being covered by a large flap gotten from the sole and inner border of the foot, the scar being horizontal and upon the outer and anterior aspects of the foot. The position is as in the preceding opera-

tions, the surgeon so manipulating the foot with his left hand as to turn it from side to side in following the complicated incisions.

The landmarks are the tendo Achillis, the external malleolus, the base of the fifth metatarsal, the joint between the scaphoid and cuneiform, the joint-line between the scaphoid and the internal and the middle cuneiforms, the tendon of the extensor longus hallucis, the cuneometatarsal joint of the great toe, and the external tuberosity of the os calcis.

The incision begins at the outer margin of the insertion of the tendo Achillis, curves upward to a point 2.5 cm. (1 inch) below the external malleolus, passes horizontally forward at this level, parallel with the border of the foot, until a point is reached on a line connecting the base

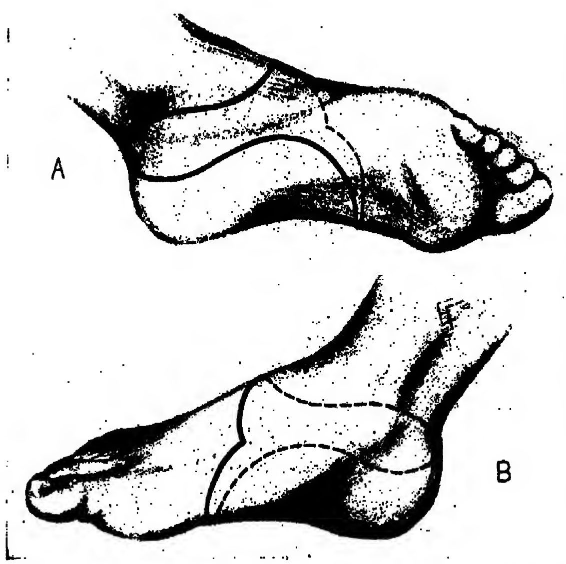


FIG. 361.—SUBASTRAGALOID DISARTICULATION OF FOOT BY LARGE INTERNOPLANTAR FLAP (FARABEUF).
A, Outline of incision upon outer aspect of foot; B, outline of incision upon inner aspect.

of the fifth metatarsal with the joints between the scaphoid and cuneiform bones, thence curves sharply across the dorsum, just anterior to the joint-line, between the scaphoid with the internal and middle cuneiforms, until the tendon of the extensor longus hallucis is reached, thence curves slightly forward to cross the inner border of the foot in the line of the cuneometatarsal joint of the big toe, thence sweeps across the center of the sole, and, curving into the outer border of the foot, follows that border to the external tuberosity of the os calcis, thence upward, to end at the insertion of the tendo Achillis, at the point of beginning (Fig. 361).

The above incision is now everywhere deepened to the bone along the line of the retracted skin and fascia, using a stout knife, and cutting

with force as the parts are put upon the stretch, cutting all the tendons cleanly, and opening no joints. Now flex the leg upon the thigh, turn the knee inward, and press the inner side of the leg onto the table, so that the outer side of the leg presents, and the foot is beyond the edge and kept upon the stretch. Dissect up, cleanly from the bone, the outer dorsal portion of the flap, until the head of the astragalus is exposed in front and the tendo Achillis behind; divide the tendo Achillis, enter the astragaloscaphoid joint on its dorsal aspect, keep the knife in the interarticular line, and cut backward between the astragalus and os calcis, passing beneath the tip of the external malleolus to the already cut tendo Achillis, severing all ligaments, and everting the os calcis as the ligaments are cut, until the under surface of the astragalus is free. The foot is further twisted into extreme varus, and the inner and under surfaces of the os calcis are bared, working from the inner toward the under and outer surfaces of the os calcis, by cutting with short strokes of a strong knife, and closely hugging the bone to avoid damaging important structures on the inner aspect, especially the vessels which supply the flap. By the time the externo-plantar border of the os calcis is reached, the dorsum of the foot will be looking downward. Free the skin from the posterior surface of the os calcis carefully, so as not to score the integumentary parts. Sever any remaining connection. Cut the anterior and posterior tibial nerves high up. The following arteries are encountered in the direction of the incision, and will require ligation: the posterior peroneal, the anterior peroneal, the dorsalis pedis, the internal and external plantar. Provide temporary drainage by puncturing the heel portion of the flap. Quilt the muscles and the tendons. Suture the flap in an external and anterior horizontal line. Dress the stump upon a posterior splint.

Disarticulation of Foot at Ankle-joint, with Removal of Malleoli and Articular Surface of Tibia *(By Heel Flap—Symes' Operation)*.—The operation is sufficiently described in the above title.

The patient is supine, with the foot elevated and over the edge of the table. The assistant steadies the leg with one hand and holds the foot at a right angle to the leg by grasping the toes with the other hand. The surgeon sits for the plantar and stands for the dorsal incisions. The landmarks are the outline of the ankle-joint and the malleoli.

The plantar incision begins at the tip of the external malleolus, on the right side (the surgeon's left palm resting on the instep, with the forefinger and thumb upon the malleoli), passes vertically down the outer side of the foot across the sole, and vertically up the inner side of the foot to a point 1.3 cm. (½ inch) below the tip of the internal malleolus. This incision passes exactly at a right angle to the long axis of the foot, in a straight line between these two points; if inclined forward, the flap is very difficult to dissect from the os calcis; if inclined backward, it is easier to separate, but apt to form a scanty covering, with imperfect vascular supply. If the inner limb of the vertical incision passes up to the posterior border of the inner malleolus, the posterior tibial artery is more in danger of being divided before its

bifurcation and the main branch of the flap, the internal calcaneal of the external plantar, is lost. The above incision is made in two cuts, each from the malleolus to the center of the sole. The dorsal incision (surgeon's left palm to the sole, with the thumb and first finger grasping the margins of the foot and extending it) connects the upper ends of the plantar incision by an incision sweeping straight across the front of the ankle. The dorsal and plantar incisions are approximately at a right angle to each other (Fig. 359, C, C, and Fig. 360, C, C).

The plantar incision, made with a heavy knife, passes directly and cleanly to the bone. The large heel flap is freed from the os calcis as far as its tuberosities, partly by the use of the left thumb, partly by a stout knife cutting close to the bone. It is possible, but difficult and unadvisable, entirely to dissect and retract the heel flap from the tuberosities and posterior surface of the os calcis from the plantar wound. With the foot fully extended, the dorsal incision is now made directly to the bone, cutting the tendons and ligaments cleanly. This incision cuts directly through the anterior ligament of the ankle-joint and opens the articulation. The disarticulation is continued by cutting the lateral ligaments from within outward, and completed by similarly cutting the posterior ligament. The tendo Achillis is now cut. The foot is then drawn downward and forward and the posterior and lateral surfaces of the os calcis dissected free of the heel covering by working from behind downward and forward with short, close strokes of the knife while the parts are under tension. The malleoli are now closely cleared of their soft parts, hugging the bones and guarding the flaps. The soft parts are well retracted, and the tibia and fibula are sawn transversely about 6 mm. (¼ inch) above the inferior border of the tibia (which will remove the articular surface of the dome), the malleoli being steadied by forceps during the sawing. Ligate the anterior tibial, external and internal plantar, and probably the external and internal malleoli of the anterior tibial, the anterior peroneal, the internal malleolar of the posterior tibial, and the internal and external saphenous veins. Cut all the nerves short, especially those of the heel flap, which is bent over the ends of the sawn bones. Suture the heel flap to the dorsal incision, using tension-sutures in addition to coaptation sutures, if there be much strain upon the suture line. Institute drainage through a counteropening in the heel flap if indicated. So dress the part, with a posterior splint included, as to draw the heel flap forward and upward.

Disarticulation of Foot at Ankle-joint, with Removal of Malleoli, Articular Surface of Tibia, and Anterior Part of Os Calcis (*By Heel Flap—Pirogoff's Operation*).—An intracalcaneal osteoplastic amputation of the foot. The operation is very similar to Symes', except that the anterior and major portion of the os calcis is sawed off and the remaining posterior portion, which is left in the heel flap, is adjusted to the transversely sawn tibia and fibula.

The position and landmarks are the same as in Symes' operation (p. 852).

The plantar incision (in the case of the right foot) begins just anteriorly to the tip of the external malleolus, passes vertically down the outer side of the foot, across the sole, and vertically up the inner side of the foot to a point 1.3 cm. (½ inch) below and a short distance anteriorly to the tip of the internal malleolus (which points are a little anterior to those of Symes' operation). The dorsal incision is somewhat more convex; that is, it passes further down on the dorsum of the foot than does Symes' (Fig. 359, D, D′, D″, and Fig. 360, D, D′, D″).

These incisions are made and deepened in the same manner as in Symes' operation. The heel flap is not freed back from the plantar surface of the os calcis quite to its tuberosities. The disarticulation is accomplished as in Symes'. The foot is placed in extreme extension and the upper surface of the os calcis exposed, but the tendo Achillis not cut. The whole of the os calcis having been freed except its posterior third, the saw is applied (with the foot in extension) to the upper surface of the os calcis, 1.3 to 2 cm. (½ to ¾ inch) behind the astragalus, and made to saw its way obliquely downward and forward (or more nearly vertically, in the extended position of the foot) in a line about parallel with the now distorted heel incision, all the soft parts being carefully retracted the while, especially the inner arteries. The lower ends of the tibia and fibula are then freed as in Symes,' and are sawed off in the same manner, except that, after entering the anterior surface of the bone about 6 mm. (¼ inch) above the inferior border of the tibia, the section is so made that the saw emerges posteriorly about 1.3 cm. (½ inch) higher than on the anterior surface (to be parallel with the section of the calcaneum). Ligate the same vessel as encountered in Symes' operation. Cut the nerves short and the loose tendons. Approximate the sawed calcaneum to the sawed tibia, and suture the plantar flap to the dorsal incision.

Amputation of Leg through Supramalleolar Region (*By Oblique Elliptical Incision—Guyon's Supramalleolar Operation*).—An operation somewhat resembling Symes', the tibia and fibula being divided below the medullary canal, and the ends of the bones covered by a heel flap of skin and muscles.

In operating upon the leg, in general, the limb projects over the edge of the table, the patient being supine, the surgeon standing to the outer side of the right and inner side of the left, the assistant steadying the part to come away. In the present operation the surgeon grasps the foot in his left hand and manipulates it so as readily to expose the line of incision. On the right the foot is turned inward and the incision begins at the outer side of the heel, crosses the outer aspect of the foot, which is then turned upon its outer side, and the incision carried to the heel along the inner aspect. On the left, the incision may begin in front, with the foot upon its inner side.

The landmarks are the ankle-joint, the malleoli, and the greatest prominence of the heel.

The incision begins, say, on the anterior aspect of the ankle, opposite the center of the ankle-joint, curves obliquely downward and backward

over the lateral aspects of the foot, just skirting the inner malleolus, and passing slightly in front of the external malleolus, ending over the summit of the curve of the heel. The incision may be made from the instep to the heel, or vice versâ (Fig. 360, E, E').

The above incision is made through the skin and fascia, and is then everywhere deepened to the bone, except that the ankle-joint is not opened and the peronei tendons behind the external malleolus are not cut until the soft parts have been cleared above the ankle-joint. The soft tissues are now carefully freed up about 5 cm. (2 inches) above the tips of the malleoli, providing a musculoperiosteal covering, using great care to preserve the vessels on the inner aspect, the surgeon standing for the anterior clearing, and sitting (or elevating the limb) for the posterior clearing. The tendo Achillis is divided. The peronei tendons are cut at about the level of the ankle. The ankle-joint is not opened. The anterior tibial, posterior tibial, termination of the peroneal, and anterior peroneal vessels are ligated. The nerves and tendons are cut especially short. It is probably better to dissect out the posterior tibial nerve. The convex heel flap is then sutured to the upper concave incision, and the stump dressed as in Symes' operation.

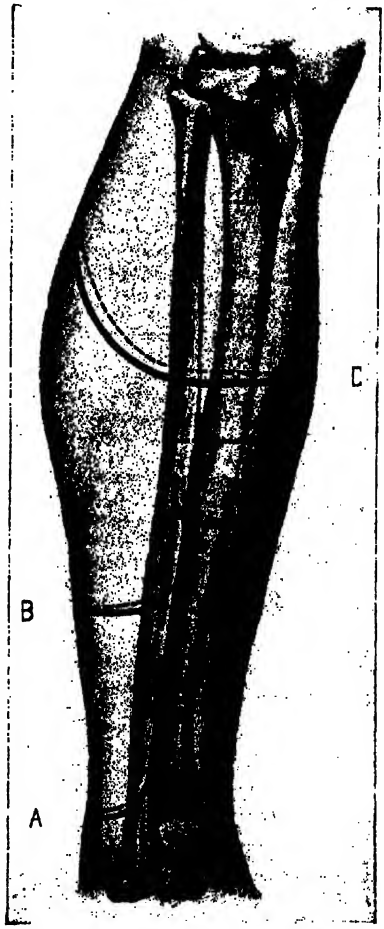


FIG. 362.—AMPUTATIONS ABOUT THE LEG. A, Through lower third of leg, by large posterior and small anterior flap; B, through middle third, by long posterior and short anterior (Hey's operation); C, through upper third, by bilateral hooded flaps (Stephen Smith's operation).

Amputation through Lower Third of Leg (*By Large Posterior and Small Anterior Flaps—Farabeuf*).—The operation is usually known as a large posterior flap method, the anterior flap supplying a small part of the covering. Both flaps are of skin and muscle. The posterior flap, which forms the bulk of the covering, is derived really more from the postero-internal aspect, and the anterior or smaller flap, which is about one-fourth the length of the larger, from the antero-external aspect.

For the position see the supramalleolar amputation (p. 854), and under Incision below. The landmark is the saw-line.

The incision for the posterior flap begins (on the right side) with the leg turned to present the inner side, at the saw-line, on the inner side of the leg, and passes vertically down in front of the inner border of the tibia for a distance equal to about 1¼ diameters of the limb at the saw-line, then round across the posterior aspect of the leg. The outer limb of the incision begins, with the leg turned to present the outer side, at the saw-line, on the outer side of the leg, and passes vertically down just behind the fibula, for a distance equal to one and a quarter diameters of the leg at the saw-line, then rounds across the posterior aspect of the leg to meet the inner incision. The anterior flap is made by a transverse incision, slightly convex downward, passing between the two vertical incisions, at a distance below their upper ends, equal to about one-fourth of the length of the posterior flap (Fig. 362, A).

These incisions having been made through the skin and fascia, the tendo Achillis is divided on a line with the retracted skin, and the leg is turned to present its inner side, and the upper part of the inner incision is deepened for a length of about 5 cm. (2 inches) by freeing the muscles from the tibia. The leg is now turned to present the outer side, and the upper end of the outer incision is similarly deepened for a distance of about 5 cm. (2 inches) by freeing the muscles from the fibula. The leg is flexed during these incisions. Through these two opposite openings the left thumb and index are thrust, meeting in the center, and thus the soft parts are picked up and drawn from the bones, the limb still being flexed. A long knife is passed through this opening and made to cut its way out on a line with the retracted skin, bluntly beveling the flap. The anterior incision is now deepened to the bone on a line with the retracted skin. The soft parts are then freed back to the saw-line, the interosseous membrane being divided transversely, and the periosteum having been circularly divided a distance below the saw-line sufficient to furnish a covering of one diameter of each bone at the saw-line. The soft parts are retracted and the bones are sawed, beveling the prominent anterior border of the tibia. Ligate the anterior tibial, posterior tibial, peroneal arteries, and internal and external saphenous veins. Suture the periosteomuscular coverings over the ends of the bones. Quilting of the muscles is particularly indicated, as the heavy posterior muscles are apt to sag backward. Dissect out the posterior tibial nerve. Dress the stump on a posterior splint.

Osteoplastic Amputation of the Leg *(By Long Posterior and Short Anterior Flaps)*.—Having amputated the leg by a long posterior and short anterior flap, a vertical section is made from the anterior surface of the tibia, forming an adherent bone-flap, which is broken backward, and subsequently applied to the transversely divided portions of the tibia and fibula.

The position is the same as in amputating the leg by anteroposterior flap methods, see above. The landmark is the saw-line.

The posterior flap, having a base equal to one-half the circumference of the limb at the line of the bone section, is made by an incision

beginning just below the line of the division of the bone, and passing down behind the posterior border of the tibia and fibula, rounding out into the posterior aspect of the limb at a distance below the saw-level equivalent to about one diameter of the limb at the level of the bone-section. The anterior flap is one-third the length of the posterior, beginning and ending in the same lines laterally.

Having outlined both flaps through the skin and fascia, the soft parts of the posterior flap are divided to the bones, cutting obliquely from the line of the retracted skin. This flap is then retracted, en masse, up to the saw-line. The anterior flap is dealt with in the same way, both flaps consisting of all the soft parts down to but not including the periosteum. Having retracted the soft flaps well out of the way, thus exposing the tibia and fibula with their undisturbed periosteum, the bone-flap to be taken from the tibia is planned. A sufficient length of bone-flap is calculated to cover the transversely divided ends of the tibia and fibula—the bone-flap coming from the antero-internal aspect of the tibia. The making of this flap is somewhat complicated, but is well shown in the diagrammatic Figs. 364, 365, and 366. Having completed the division and retraction of the soft parts, the tibia and fibula are sawn transversely at H and F, Fig. 364. The tibia is sawn longitudinally from H to G, along AC and BD. The fibula is then sawn completely through at E, and the tibia is divided at CD, nearly to but not through the periosteum toward G. The portion of the tibia between the lines AHB and CGD represents the osteoplastic flap. The periosteal flap is now broken back through the limited portion of bone still holding it by means of a chisel inserted in the saw-section and given a slight tap. Having hinged back the bone-flap, room has now to be provided for its bending forward over the transversely divided tibia and fibula. This is accomplished by making another transverse division of both bones at a height above the preceding section equivalent to the thickness of the bone-flap (Fig. 365). The completed bone sections are shown in Fig. 366, where the redundancy of periosteum is shown, furnishing the hinge. The bone-flap is now dropped over the ends

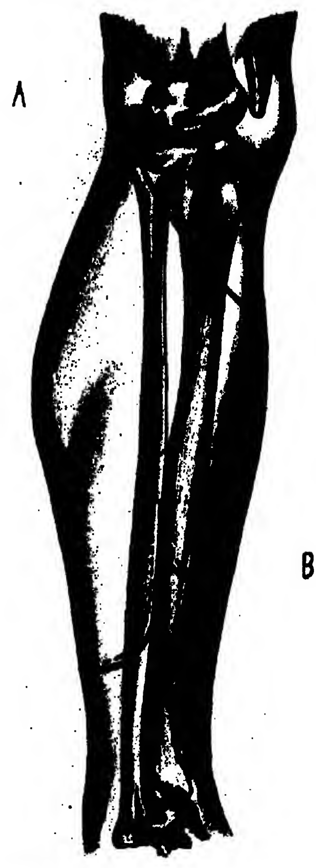


FIG. 363.—AMPUTATIONS ABOUT THE KNEE AND LEG.

A, Disarticulation at the knee-joint by an oblique incision; B, osteoplastic amputation of the leg by long posterior and short anterior flap.

of the bones and is held in place either by suturing its periosteum to that of the tibia and fibula, or by carrying an absorbable suture through a hole previously drilled through both bones, as shown in Fig. 367. Having united the bone-flap to the tibia and fibula, the larger posterior flap of soft parts is brought over the bone-flap and sutured to the

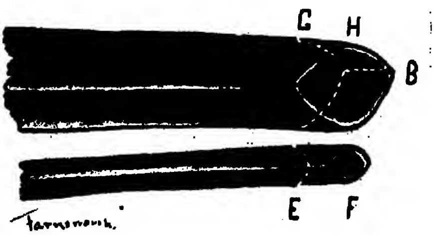


FIG. 364.—LINES OF SECTION OF BONES IN THE OSTEOPLASTIC AMPUTATION OF THE LEG.

Having completed the division and retraction of the soft parts, the tibia and fibula are sawn transversely at H and F; the tibia is sawn longitudinally from H to G, along AC and BD; the fibula is then sawn through completely at E, and the tibia is divided at CD, nearly to but not through the periosteum toward G; the portion of the tibia between the lines AHB and CGD represents the osteoplastic flap.

contour of the smaller anterior flap, the muscle structures in the two flaps being supported by buried absorbable sutures.

Amputation through Middle Third of Leg (*By Long Posterior and Short Anterior Flaps—Hey's Operation*).—The covering is one of skin- and muscle-flaps furnished almost entirely from the posterior aspect of the leg. The method is frequently termed simply a long

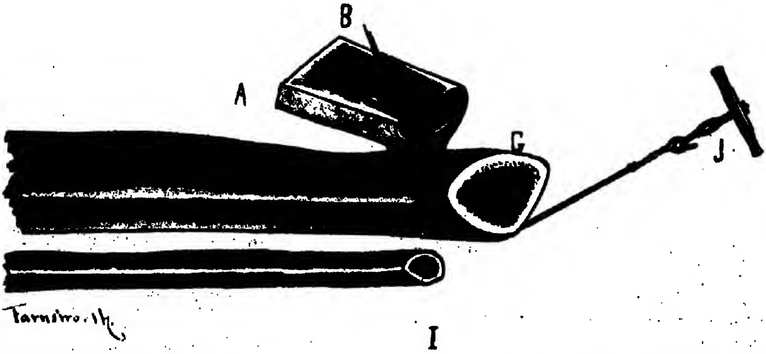


FIG. 365.—REMOVING SECTIONS OF TIBIA AND FIBULA TO ENABLE THE TIBIAL BONE-FLAP TO BE HINGED OVER UPON THE SAWN FIBULA.

A, A third transverse section of both bones is here made for this purpose, at a height above the preceding section equivalent to the thickness of the bone-flap.

posterior flap operation, and differs but little from Farabeuf's amputation through the lower third of the leg.

The position is as in Guyon's supramalleolar amputation (p. 854), and as given under the incision below. The landmark is the saw-line.

The posterior flap is U-shaped, its breadth is equal to half the circumference of the limb at the saw-line, and its length is equivalent

to one-half diameter of the limb at that line. It begins 2.5 cm. (1 inch) below the saw-line (instead of at that line). The inner limb passes vertically down the leg, just behind the internal border of the tibia, rounding broadly into the posterior aspect of the limb, the outer limb passing vertically downward just behind the fibula, posterior to the peronei muscles, and rounding broadly into the posterior aspect of the leg, to unite with the opposite limb of the incision. The anterior flap

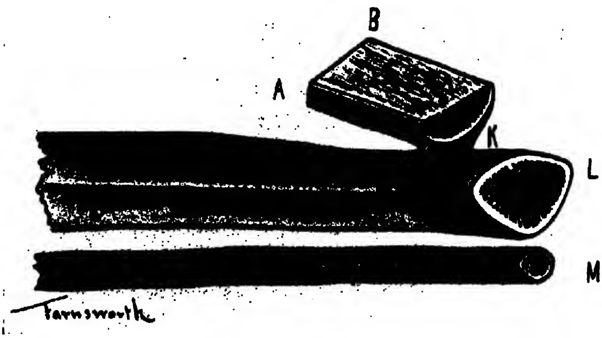


FIG. 366.—THE OSTEOPLASTIC AMPUTATION OF THE LEG.
The bone-flap, AB, with its periosteal hinge, K, is here shown ready to be applied to the transversely divided ends of the tibia and fibula, L, M. Owing to the removal of the piece of tibia and fibula accomplished by the last section (Fig. 365) this hinging is made possible.

is about one-third the length of the posterior, and is made by joining the vertical limbs of the posterior flap at their upper thirds, by a transverse incision, with slight downward convexity, across the front of the leg. In these incisions the knee is flexed and the leg is laid on the outer side, while the inner incision is being made from above downward, and vice versâ (Fig. 362, B).

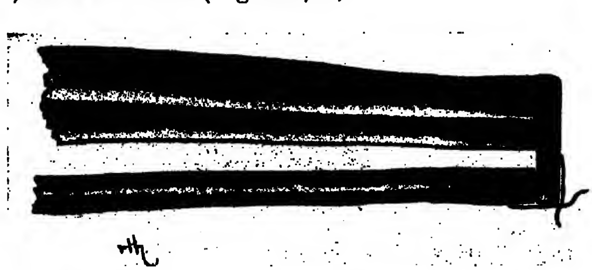


FIG. 367.—THE OSTEOPLASTIC AMPUTATION OF THE LEG.
The tibial flap, with its adherent and continuous periosteum, is here shown applied to itself and fibula, a suture, passed through drilled holes, holding the parts in contact.

The above incisions pass through the skin and fascia only. With the leg flexed on the thigh and the knee everted, the gastrocnemius is held up by the thumb and first finger and cut from without, on a line with the retracted skin and fascia. The upper parts of both vertical incisions are now deepened, the inner to the tibia, the outer to the fibula, behind the peronei muscles. The left thumb and index are inserted into these slits and the muscles drawn outward. The muscles

having been detached from the bones and interosseous membrane above, a long knife is passed between the bones and separated muscles and is made to cut its way outward along the line of the retracted skin. The interosseous membrane is divided transversely and the periosteum circularly, and all the soft parts retracted upward for the 2.5 cm. (1 inch) between the saw-line and the beginning of the flap. The flaps are now retracted, the bones divided, and the prominent crest of the tibia beveled. The anterior tibial, posterior tibial, and peroneal arteries are ligated. The musculoperiosteal coverings are sutured over the ends of the bones. The muscles are quilted with especial care, owing to the tendency of the posterior flap to sag backward. The large posterior and short anterior flaps are then sutured together, and the stump supported upon a posterior splint.

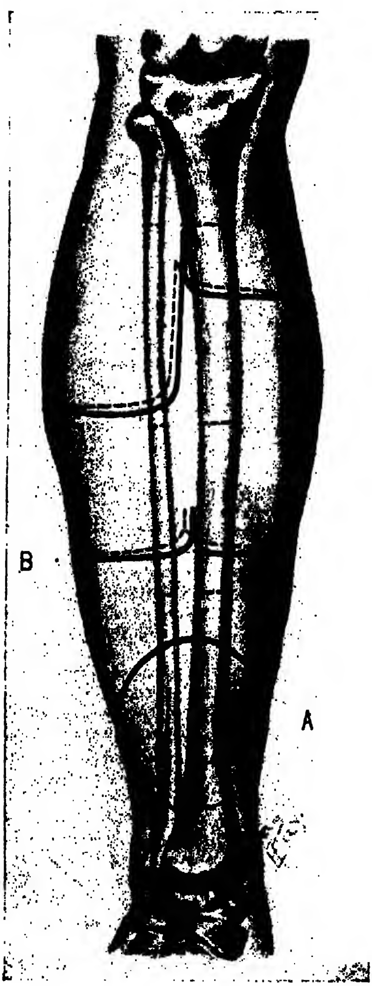


FIG. 368.—AMPUTATIONS ABOUT THE LEG.
A, Through lower third of leg, by oblique circular method; B, through middle third, by modified circular method; C, through upper third, by large external flap.

Amputation through Upper Third of Leg (*By Large External Flap—Farabeuf*).—The stump is covered by a large U-shaped flap of skin and muscles raised from the external aspect of the leg.

The patient lies in a supine position, with the leg projecting over the side of the table, the knee flexed, and the leg lying on the inner side for the incision of the external flap, and on the outer side for the transverse incision. The surgeon stands to the outer side of the right and the inner side of the left leg. The landmark is the saw-line.

The U-shaped external flap is equivalent in length to one diameter of the limb at the saw-line; it begins opposite the saw-line anteriorly, passes vertically downward parallel with and just internal to the anterior border of the tibia, rounds across the external aspect of the leg, and passes vertically upward directly opposite the anterior incision, but ends about 4 cm. (1½ inches) below the saw-line. The transverse incision passes transversely across the inner aspect of the limb, with slight downward convexity, connecting the upper end of the posterior

incision with a point on the anterior incision 4 cm. (1½ inches) below its beginning. The external flap may be cut or outlined with one sweep of the knife, but it is better to complete it in two strokes (Fig. 368, C).

Beginning with the external flap, the above incision is deepened along the line of the retracted skin, and the large flap of soft parts to the bones raised. To accomplish this the incision is first deepened along the anterior limb by cutting down upon the anterior border of the tibia from above downward. The tibialis anticus is thus freed from the bone. The left fingers of the operator, slipped between the muscles and the bones, draw it outward, while the short knife continues its downward incision, beveling obliquely the lower portion of the muscular mass toward the extremity of the flap. Thus the entire muscle mass is separated from the tibia, interosseous membrane, and fibula, by the use of the knife, fingers, and the elevator. Care is taken that the anterior tibial artery is not divided before the free end of the flap is reached, the integrity of which so largely depends upon this vessel. If the parts are freed up too high, especially posteriorly, where the vertical incision is shorter than the anterior, the anterior tibial artery may be severed before traversing the interosseous membrane. The transverse incision crossing the inner aspect of the limb is now deepened by cutting from without inward on the line of the retracted skin and fascia. The interosseous membrane is divided transversely. The periosteum is circularly divided around the tibia and fibula. The periosteum and soft parts are then freed up to the saw-line and retracted, while the bones are divided, the prominent margin of the tibia being beveled from above downward and from before backward. The fibula is sawed a little higher than the tibia, and beveled from above downward and from without inward. The anterior tibial, posterior tibial, peroneal, muscular branches to the gastrocnemius and soleus, and the nutrient arteries are ligated. All nerve-trunks which are apt to be pressed upon are dissected out. The muscles are quilted. The margins of the external flap are sutured to the inner transverse incision, and the limb dressed upon a posterior splint.

FIG. 369.—BIER'S OSTEOPLASTIC AMPUTATION OF THE UPPER THIRD OF THE LEG.

Lines for the incision of the soft parts forming an antero-internal cellulocutaneous flap.

Osteoplastic Amputation through Upper Third of Leg (*By Antero-internal Flap—Bier's Method*).—An osteoplastic flap is taken from the antero-internal aspect of the tibia, in the upper third of the leg, and applied to the transversely divided tibia and fibula.

The position is the same as for amputations through the upper part of the leg (p. 860).

The landmark is the saw-line, which may be at any height of the leg, but is usually in the neighborhood of the junction of the upper and middle thirds (Fig. 369).

An antero-internal flap of skin and connective tissue is outlined, having a base equal to one-half the circumference of the limb at the saw-line, and whose length is somewhat greater than the diameter at that line. The upper limits of this flap are connected by a semicircular incision with slight downward dip at its center and passing posteriorly.

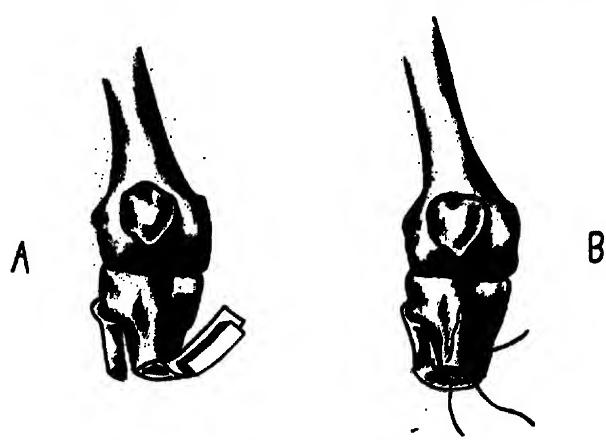


FIG. 370.—BIER'S OSTEOPLASTIC AMPUTATION OF THE LEG.

A, Showing manner of raising an osseoperiosteal flap from tibia; B, showing bone-flap brought over sawed ends of tibia and fibula, and its periosteal margins, sutured to the margins of periosteum around tibia and fibula. The osseoperiosteal flap is here shown separated from its soft parts, to which it should be adherent. (Modified from Bier.)

Having carried these incisions through the skin and fascia, the large antero-internal flap is dissected back and turned upward upon the limb. The periosteum is incised upon the subcutaneous aspect of the tibia, transversely at the lower limit of the flap, and vertically along the borders of the tibia, sufficiently to plan for the formation of the periosteally covered bone-flap. A bone-flap, with periosteum attached, is now raised from this aspect of the tibia by means of a Gigli-Haertel saw, calculated to cover the transversely divided tibia and fibula. The bone-flap is broken back at its base, the periosteum maintaining a hinge-connection with the upper part of the bone (Fig. 370, A). This bone-flap is turned upward and backward, and the limb is amputated at the level of the upper limit of the limbs of the antero-internal flap by a transverse incision. The vessels are secured and the nerves and tendons cut short. Enough of the upper end of the bone-

flap is removed with a saw to enable the intervening hinge of periosteum to bend over the end of the bone without too great stretching. Having approximated the sawn bone-flap to the sawn ends of the tibia and fibula, it is held in place by suturing the adjacent margins of the periosteum with absorbable sutures, as indicated in Fig. 370, B. The skin-flap is finally turned down and sutured to the transversely divided skin posteriorly.

Disarticulation at Knee-joint (*By Bilateral Hooded Flaps—Stephen Smith*).—Two lateral flaps of skin and fascia are raised from the outer side of the upper portion of the leg by an incision extending much higher behind than in front. These are retracted to the articular line, where the soft parts are circularly divided, after which the bilateral hooded flap is dropped over the disarticulated end of the femur, the scar being posterior and in the groove between the condyles.

The patient is in the supine position, with the limb over the edge of the table, held horizontal for skin incisions and vertical when freeing back the soft parts. The surgeon, standing to the outer side of the right and the inner side of the left limb, places the left thumb upon the anterior border of the tibia to mark the upper limit of the anterior incision, and his left index opposite the posterior joint-line to mark the upper limit of the posterior incision, leans over the patient, and cuts from behind forward on both sides, the incisions meeting at the highest point of the anterior incision. The landmarks are the knee-joint and the tubercle of the tibia.

FIG. 371.—AMPUTATIONS ABOUT THE LEG AND THIGH.

A, Through upper third of leg, by equal lateral flaps; B, disarticulation at knee, by bilateral hooded flaps (Stephen Smith's operation); C, through lower part of thigh, by oval method.

The highest point of the posterior incision is opposite the joint-line, and the highest point of the anterior incision is 2.5 cm. (1 inch) below the tuberosity of the tibia. The surgeon's left thumb marks the anterior and the index the posterior points. The incision begins posteriorly in the midpopliteal space, opposite the interarticular line, as defined by the tip of his left index, passes thence vertically down the midposterior aspect for about 5 cm. (2 inches), thence gradually diverges from the median line as it sweeps downward and outward over that

side of the limb further from the surgeon (and over which he is leaning), until about 5 cm. (2 inches) below the tubercle of the tibia, cutting a flap with convexity downward; thence curves forward and slightly upward to a point in the median line 2.5 cm. (1 inch) below the tibial tubercle, thus ending the outline of the further flap. The knife again enters posteriorly at the same point, and makes a similar incision upon that side of the limb nearer the operator, calculating that the internal

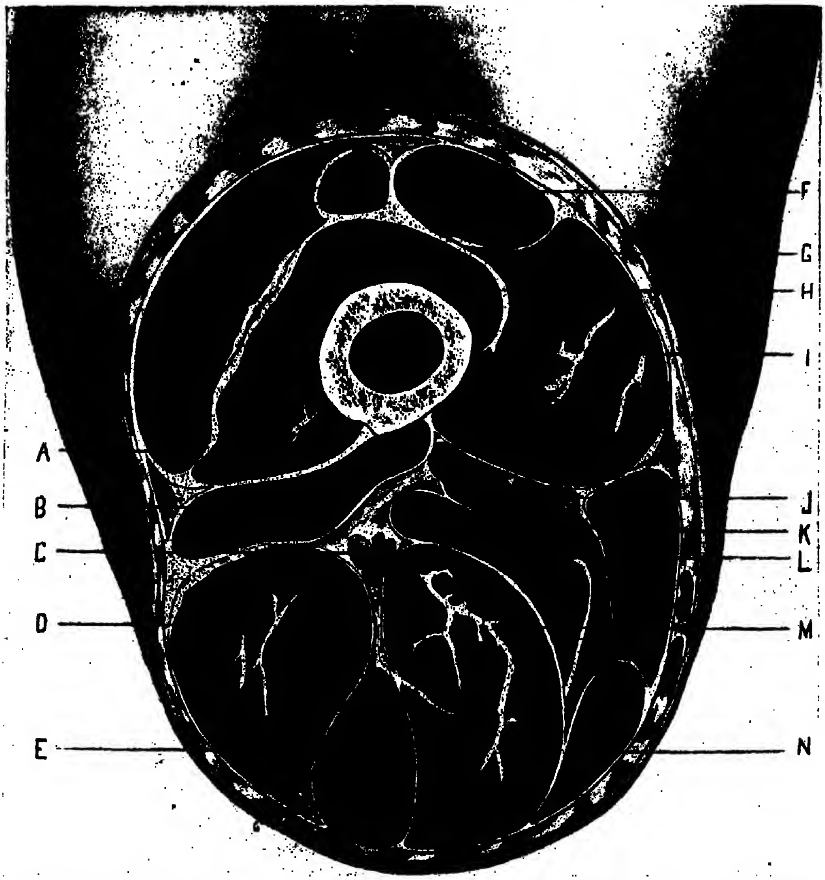


Fig. 372.—Transverse Section through the Lower Third of the Right Thigh.
A, Vastus externus; B, D, biceps; C, great sciatic nerve and vessels; E, semitendinosus; F, rectus; G, I, vastus internus; H, crureus; J, femoral vessels and long saphenous nerve; K, sartorius; L, adductor magnus; M, semimembranosus; N, gracilis. (Cross-section modified from Braune.)

flap is slightly larger to cover the larger internal femoral condyle, and meeting the first incision at the median line in front. The limb is rotated outward while the inner incision is being made, and vice versâ. The knee is extended throughout (Fig. 371, B).

The skin and fascia are now freed all around and dissected up from the muscles and tendons. The ligamentum patellæ is cut transversely against the tuberosity of the tibia as soon as reached. The skin-and-

fascia flaps are retracted up to the joint-line. Incise transversely the structures along the upper margin of the tibia, on the anterior and lateral aspects, iliotibial band, tendons of sartorius, gracilis, semitendinosus, biceps, and the lateral ligaments, and, lastly, cut the coronary ligaments binding down the semilunar cartilages, attacking them upon the sides of the joint, entering the joint between the head of the tibia and the semilunar cartilages, thus leaving these cartilages in the stump, and completing their separation by flexing the knee. Flex the knee and cut the crucial ligaments. Extend the knee and divide transversely, with one sweep of a long knife, all the soft parts opposite the posterior aspect of the joint—the gastrocnemius, popliteus, hamstring tendons, popliteal vessels and nerves, and posterior ligament. Ligate the popliteal artery and vein, sural, superior articular, and anastomotica magna branches. Suture the lateral flaps in a vertical line, the scar being eventually drawn into the intercondyloid notch. Drain temporarily through the upper end of the posterior incision.

Amputation Just above Condyles of Femur, with Splitting of Patella (*By Longer Anterior and Shorter Posterior Flaps—Gritti-Stokes' Supracondyloid Osteoplastic Amputation*).—Gritti's operation consists in the division of the femoral condyles at the level of their adductor magnus tubercle; the removal of the articular surface from the patella; the application of the sawed patella into contact with the sawed femur; and the covering of the stump with a long rectangular anterior flap. Stokes' modification consists in dividing the femur 2 to 2.5 cm. ($\frac{3}{4}$ to 1 inch) above the adductor tubercle (where the transverse section of the femur more nearly corresponds with the size of the split patella), the stump being then covered by an anterior longer, and posterior shorter, flap, the object being, in the latter case, to approximate bone sections of nearer similar size, and to bring them into contact with lesser tension.

The patient rests upon the back, drawn down upon the table so that the buttocks are near or on the edge of the table. The surgeon is upon the outer side of the right and inner side of left limb. One assistant steadies and supports the part below the site of operation, and another holds the limb, or retracts the parts, above the site of amputation. The landmarks are the adductor magnus tubercle, knee-joint, and tubercle of the tibia.

The anterior longer flap begins 2.5 cm. (1 inch) directly above the prominence of one condyle, and ends the same distance directly above the prominence of the opposite condyle, crossing the front of the knee with a broad curve just below the tubercle of the tibia. The posterior shorter flap passes, in a broad curve, between the points of beginning and ending of the anterior flap, being one-third the length of the anterior flap (Fig. 373, B).

These flaps, having been outlined through skin and fascia, are now dissected upward. The skin and fascia of the anterior flap are raised from its lower edge until the ligamentum patellæ is reached, which is cut transversely, and the flap further freed and turned up, with the

patella in it. The posterior flap of skin and fascia is then freed upward from the muscle structures. These flaps are now retracted to the saw-line (2 to 2.5 cm., or ¾ to 1 inch, above the adductor magnus tubercle) and all the soft parts, including periosteum, circularly divided to the bone, after which the bone is sawed—the main vessels may be now tied before the section of the patella, which is the most difficult part of the operation, is done. These vessels are the popliteal, muscular, articular, anastomotica magna. The patella is grasped firmly by lion-jaw forceps and held in such a way as to present its articular surface horizontally. A section of the bone is made in such a manner as to remove the articular surface of the patella. This is best accomplished by a narrow, thin saw. It may also be done with a broad chisel, and, less satisfactorily, with cutting pliers. The cut surface of the patella is then approximated to the sawed end of the femur. It may be held in place by inserting two or three ivory or steel pegs through previously drilled holes in the patella, or by wire or kangaroo tendon suturing through drill-holes near the margins of the patella and femur, or by closely suturing the fibrous parts about the patella to the fibrous or periosteal parts about the lower end of the femur. The anterior and posterior flaps are then sutured together. Firm pressure is used against the stump, in the dressing, to aid in steadying the patella against the femur.

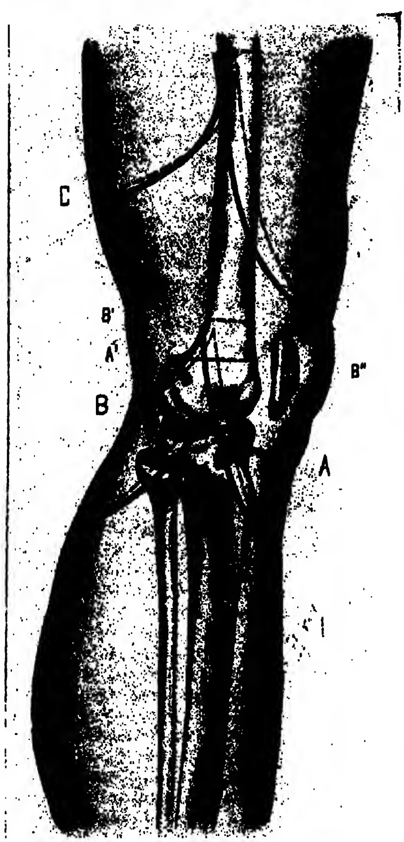


FIG. 373.—AMPUTATIONS ABOUT KNEE AND THIGH.

A, Lister's modification of Carden's transcondyloid amputation of thigh; A', division of femur in Lister's operation, on level with adductor tubercle; B, Gritti-Stokes' supracondyloid amputation of thigh, with dotted lines, B' and B", showing division of femur above level of adductor tubercle, and splitting of patella; C, through lower part of thigh, by long anterior and short posterior flaps.

Femorotibial Osteoplastic Amputation of the Lower Limb *(By Longer Anterior and Shorter Posterior Flaps—Ssabanajeff's Operation).*—The limbs are amputated through the condyles of the femur. To this sawn surface a bone-flap, with adherent soft parts, is applied. The osteoplastic flap is derived from the upper anterior aspect of the tibia.

The position is the same as for disarticulation at the knee-joint (p. 865). The landmarks are the head of the fibula, the internal

lateral ligament, the tubercle of the tibia, the tibiofibular articulation, and knee-joint.

The vertical limbs of the anterior flap pass down the midlateral aspects of the leg, from the head of the fibula on one side, and the internal lateral ligament, on the other, to near the junction of the middle and upper thirds of the leg, where they round out and meet in the anterior aspect of the part. The posterior flap is similar in form and about half the length of the anterior (Fig. 374).

Having outlined both flaps through skin and fascia, the posterior flap of skin and fascia alone is dissected up to the articulations between tibia and fibula, and between tibia and femur. The knee-joint and the

FIG. 374.—SSABANAJEFF'S FEMOROTIBIAL OSTEOPLASTIC AMPUTATION OF THE LOWER LIMB.

Lines of incision of the soft parts outlining long anterior and short posterior flaps.

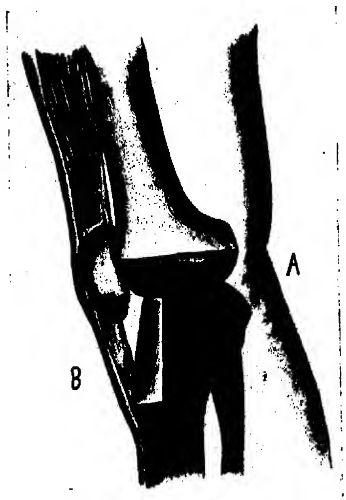


FIG. 375.—SSABANAJEFF'S FEMOROTIBIAL OSTEOPLASTIC AMPUTATION OF THE LOWER LIMB.

Lines of bone-sections: A, Portion of femoral condyles removed; B, rectangular piece of tibia, with attached patellar tendon, removed from tibia. (Modified from Ssabanajeff.)

tibiofibular joint are now opened from behind. Divide the lateral, posterior, and crucial ligaments, after having severed the overlying soft structures. The leg is now bent forward, so that the anterior surface of leg and thigh lie in contact, thus exposing the ends of the bones for sawing. The lower end of the femur is divided transversely through the expansion of the condyles (Fig. 375, A). Finally, a bone-flap is made from the upper and anterior aspect of the tibia, as indicated in Fig. 375, B, with the attachment of the ligamentum patellæ preserved, the saw traveling first down the long axis of the tibia to below the attachment of the patellar ligament, thence transversely outward to its anterior surface. The sawed surface of the tibial bone-flap is then applied to the transversely sawn femoral condyles, the patellar liga-

ment hinging around the anterior end of the bone section. The femoral condyles and the tibial bone-flaps may be drilled and sutured with kangaroo tendon, as indicated in Fig. 376, or the bony surfaces may be held in contact simply by the peripheral suturing of the soft parts. The longer anterior flap is now carried backward and sutured to the posterior flap by deep and superficial sutures.

Amputation through Lower Third of Thigh (*By Oblique Circular Method*).—Owing to greater retraction upon the posterior and inner aspects of the thigh, and in order, therefore, that the incision may eventually occupy the same height around the entire circumference of the limb, the circular incision is placed obliquely, so that it is lowest where the muscular retraction is greatest, namely, at the postero-internal aspect of the thigh.

The position is as in the supracondyloid amputation. The landmark is the saw-line.

FIG. 376.—SSABANAJEFF'S FEMOROTIBIAL OSTEOPLASTIC AMPUTATION OF THE LOWER LIMB. The rectangular portion of the excised tibia, with its attached tendon, is here shown held in contact with the sawn femoral condyles by a kangaroo tendon or wire suture passed through the drilled bone. (Modified from Ssabanajeff.)

The highest part of the circular incision is antero-external, and is a little more than half the diameter of the limb (at the saw-line) below the bone section. The lowest part of the circular incision is postero-internal, and is little less than one diameter of the limb (at the saw-line) below the bone-section, the two calculations of covering thus providing one and one-half diameters of covering in the aggregate. Such an incision is hard to follow unless previously marked (Fig. 378, A).

The above incision through the skin and fascia is made with two strokes of a long knife, the limb being conveniently rotated during the manœuver. The skin and fascia are then obliquely retracted a short way, parallel with the original incision, and the more superficial muscles circularly or slightly obliquely divided. These are further retracted and the deeper muscles circularly or slightly obliquely divided to, and including, the periosteum, to the bone, cutting each time parallel with the skin incision. The skin, muscles, and periosteum are freed up to just above the joint-line, and retracted, as in the ordinary

infundibuliform circular amputation, and the bone sawed. The femoral, anastomotica magna, descending branches of the external circumflex, perforating, and muscular branches will be cut and require ligation. The muscles are quilted in two tiers. The skin is sutured so as to make an anteroposterior scar.

Amputation through Lower, Middle, or Upper Third of Thigh (*By Long Anterior and Short Posterior Flaps*).—Two U-shaped flaps of skin and muscle are raised, anteriorly and posteriorly, the latter

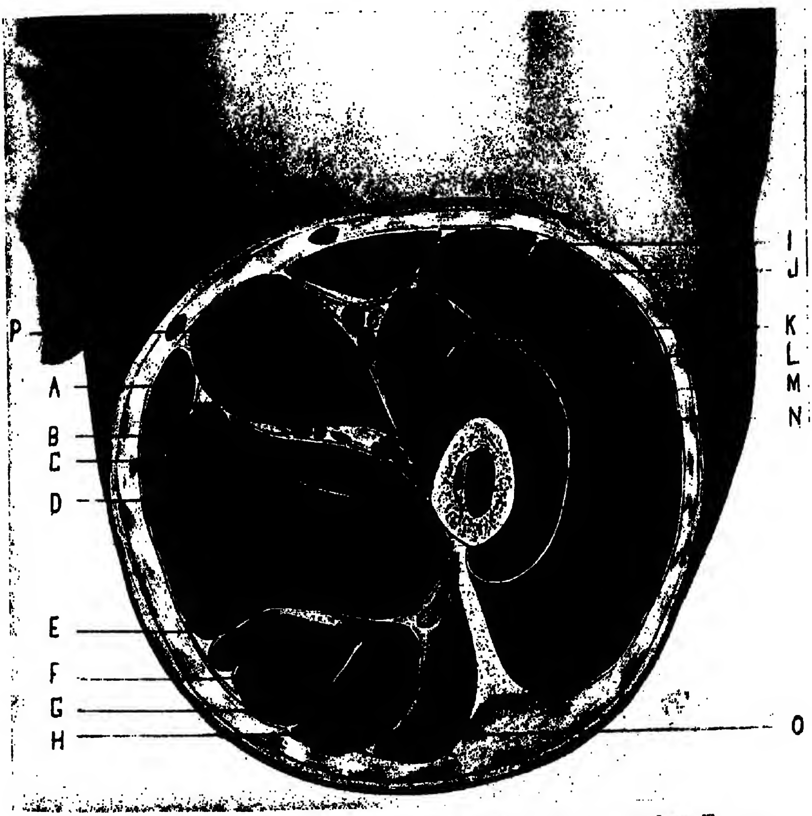


FIG. 377.—TRANSVERSE SECTION THROUGH THE UPPER THIRD OF THE LEFT THIGH.
P, Adductor longus; A, gracilis; B, obturator nerve and vessels; C, deep femoral vessels; D, adductor magnus; E, semimembranosus; F, G, semitendinosus; H, biceps; I, sartorius; J, rectus; K, superficial femoral artery, vein, and saphenous nerve; L, vastus internus; M, crureus; N, vastus externus; O, gluteus maximus. (Cross-section modified from Braune.)

being one-fourth the length of the anterior and a little narrower at the base. The position and landmarks are as in the last operation.

The anterior flap is equal, in length, to one and one-half diameters of the thigh at the saw-line, and, in width, a little more than one-half the circumference. It begins, on the right side, with the thigh rotated outward, opposite the saw-line, at about the middle of its inner aspect, or a fraction behind, passes vertically down the inner side of the thigh, rounds broadly across the anterior surface, at a distance below

the saw-line equal to one and one-half diameters, and into the outer aspect, and passes vertically upward (the thigh now rotated inward) to a corresponding point on the opposite side. The posterior flap begins and ends at the upper limits of the anterior flap, rounding across the posterior surface at a distance below the saw-line equal to a half diameter, the surgeon's hand passing beneath the thigh. In the above calculations extra length is allowed, because of the extra retraction (Fig. 373, C).

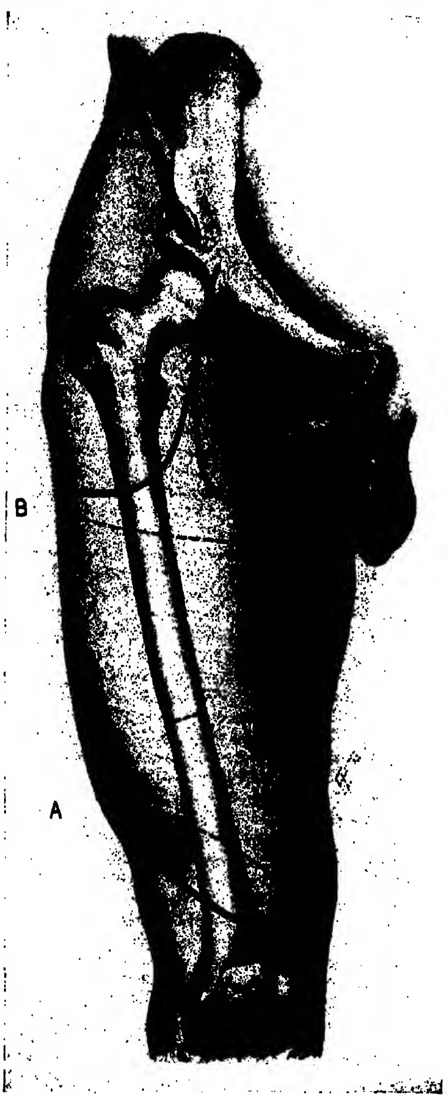


Fig. 378.—Amputations About Thigh and Hip-joint.
A, Through lower part of thigh, by oblique circular method; B, disarticulation at hip-joint, by anterior racket.

The tissues outlined in the anterior flap are now picked up by the surgeon's left hand, and, along the line of the retracted flap, the muscles are divided obliquely from without inward and upward, so beveling the flap that its extremity will consist of skin and fascia alone. The muscle tissue will begin to enter into the formation of the flap just above the extremity, and increase in thickness to the bone, into contact with which the incision will come at about one-half to three-quarters of the diameter of the femur below the saw-line, at which level the whole thickness of the muscle will be represented. The thigh is then elevated, and the posterior flap similarly cut, being obliquely beveled from without inward and from below upward, leaving skin and fascia at the lower end of the flap, and full thickness of the muscles at the upper end, where the bone is reached, the same distance below the saw-line as in the anterior flap. At the level at which the bone has been reached in the upward cutting of the flaps a circular sweep of the knife around the femur frees the periosteum. The soft parts, including

the periosteum, are then freed upward to just above the saw-line (which is everywhere easily accomplished, except at the linea aspera posteriorly), and the bone sawed. If the flaps have been made above the middle of the thigh, the femoral, profunda, descending branches

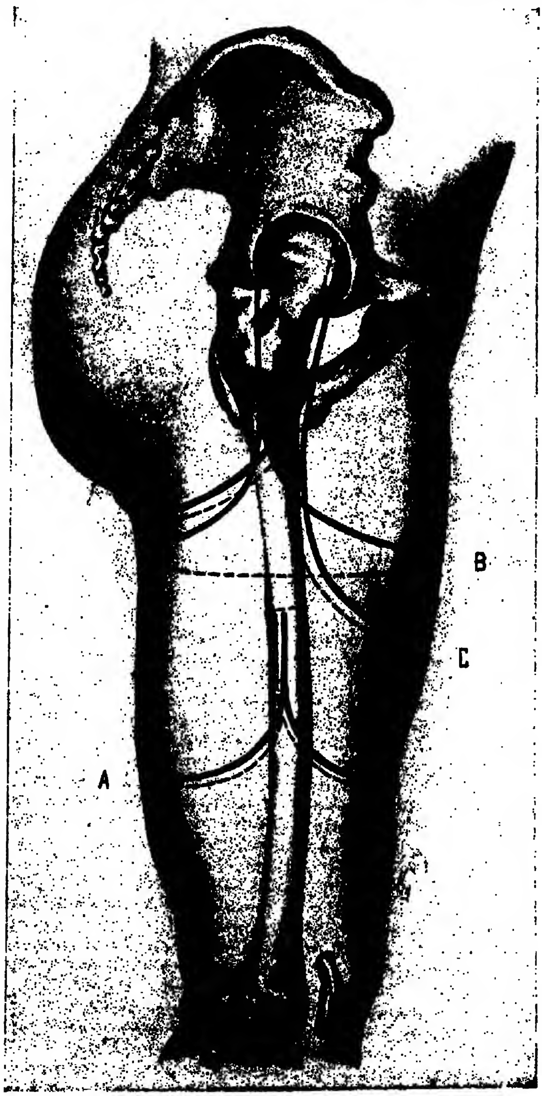


FIG. 379.—AMPUTATIONS ABOUT THIGH AND AT HIP-JOINT.
A, Through middle of thigh, by equal anterior and posterior flaps; B, disarticulation at hip-joint by external racket method; C, at hip-joint, by long anterior and short posterior flaps.

of the external circumflex, and the muscular branches will be cut in the anterior flap, and branches of the perforating arteries in the posterior flap. If the flaps have been made below the middle of the thigh, the descending branches of the external circumflex and muscular

branches will be cut in the anterior flap, and the femoral, anastomotica magna, and branches of the perforating in the posterior flap. Suture the musculoperiosteal covering over the end of the bone. Quilt the muscles of the flaps in at least two tiers, with buried chromic gut sutures. The anterior flap will drop over the end of the bone and be sutured to the posterior flap. The flaps are well supported by the pressure of the dressing, in which a posterior splint has been included, and the limb placed upon an inclined plane.

Disarticulation at Hip-joint (*By Wyeth's Method*).—Having controlled hemorrhage by means of rubber tubing wound around the thigh at its junction with the pelvis, above two large pins introduced in a special manner, a circular incision is made around the thigh,

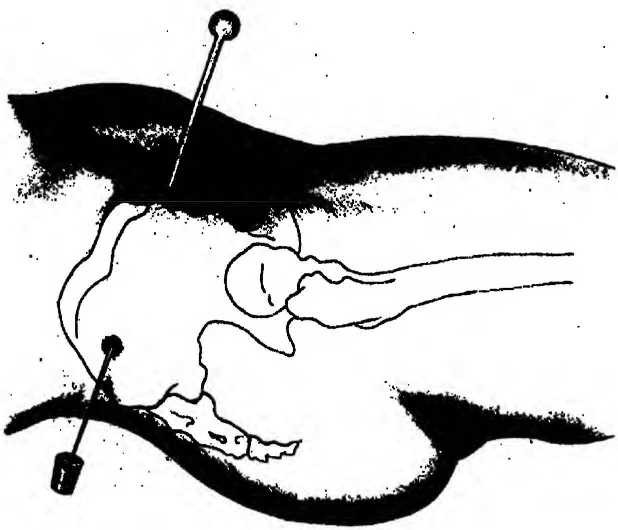


Fig. 380.—Manner of Inserting the Wyeth Pins.
The outer pin.

followed by a vertical external incision, and disarticulation at the hip-joint accomplished.

The patient lies in the supine position, drawn to the foot of the table until the sacrum rests upon the corner, with the hip projecting beyond, and kept from slipping from the table by being steadily held. The surgeon generally stands upon the outer side of both thighs, although it is more convenient to be upon the inner side of the left limb. An assistant holds and manipulates the limb projecting over the table. Another assistant steadies the pelvis and guards the method of hemorrhage control.

The manner of applying the Wyeth needles is as follows: Two steel needles, from 3 to 5 mm. ($\frac{2}{16}$ to $\frac{3}{16}$ inch) in diameter and 25 cm. (10 inches) in length, are inserted and capped with corks (to prevent their points from injuring the operator and assistants). The outer needle

enters the tissues of the outer aspect of the thigh, 6 mm. (¼ inch) below and just to the inner side of the anterior superior iliac spine, traverses the superficial muscles and fascia upon the outer side of the hip, and

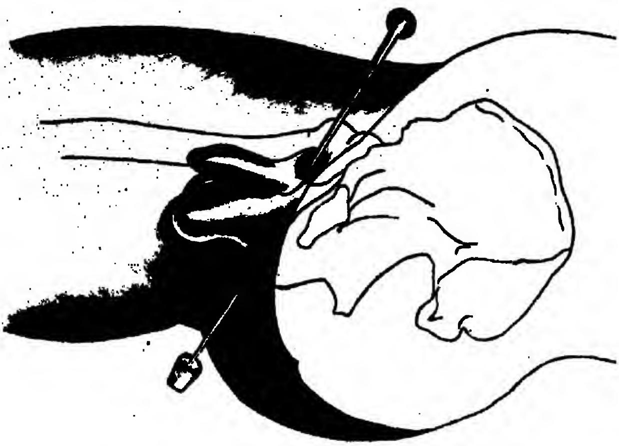


FIG. 381.—MANNER OF INSERTING THE WYETH PINS.

The inner pin. After both pins have been inserted, the rubber tubing is applied above them, as shown in their use at the shoulder-joint (Fig. 347, p. 828).

emerges on a level with and about 7.5 cm. (3 inches) external to the entrance (Fig. 380). The inner needle enters the tissues of the inner

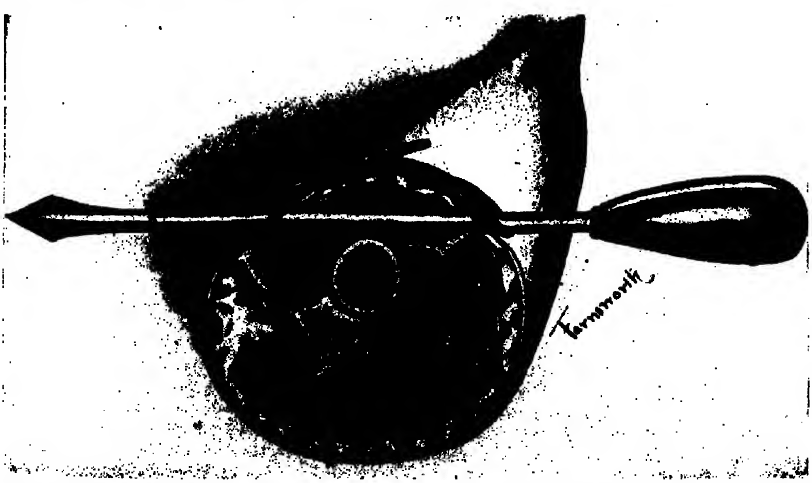


FIG. 382.—MANNER OF USING TRENDELENBURG'S ROD FOR THE CONTROL OF HEMORRHAGE IN AMPUTATIONS NEAR THE HIP-JOINT.

The rod is thrust through the limb beneath the femoral vessels, which are then constricted by a rubber band wound in figure-of-eight fashion about the rod. (Cross-section adapted from Braune.)

aspect of the thigh internal to the saphenous opening, and about 1.3 cm. (½ inch) below the crotch, traverses the adductors, and emerges 2.5 cm. (1 inch) below the tuberosity of the ischium (Fig. 381). White

rubber tubing about 7 mm. (⅓ inch) in diameter is wound tightly four or five times around the thigh above the fixation needles, and clamped. This rubber band compresses the common femoral against the rim of the pelvis, anteriorly, and the gluteal, sciatic, and internal pudic against the margin of the great sacrosciatic notch posteriorly.

Fig. 383.—Amputations through Thigh and at Hip-joint.

A, Through lower part of thigh by modified circular method; B, disarticulation at hip-joint by Wyeth's method.

The landmarks are the great trochanter and the points for the passage for the needles.

A circular incision is made around the thigh, about 15.3 cm. (6 inches) below the center of the anterior aspect of the rubber tourniquet. The vertical incision passes vertically down the external aspect of the thigh, directly over the great trochanter, passing in a straight line from the tourniquet to the circular incision (Fig. 383, B).

The circular incision passes through the skin and fascia alone. These are dissected up to the level of the lesser trochanter, that is, for about 5 cm. (2 inches). At this level the muscles are circularly divided to the bone, on a line with the retracted skin and fascia. The vertical incision is now made from the tourniquet down to the circular division, passing directly over the great trochanter. The larger vessels are at once tied, the femoral and profunda arteries and veins, and any other prominent vessel. Through the vertical incision, which has extended, at one sweep, directly through the skin, fascia, muscles, and periosteum to the bone, the soft parts are all cleared, as subperiosteally as possible, from the shaft and tuberosities of the femur. Retract the soft parts and divide the capsular ligament transversely over its outer aspect. Manipulate the limb as a lever, nicking the cotyloid ligament to let in air; cut the ligamentum teres and disarticu-

late by thrusting the head of the femur upward and outward. If not already severed, divide the posterior aspect of the capsule, and any retaining structures, and remove the limb. If enucleation be difficult, which rarely is the case in this extensive exposure, the margin of the acetabulum can be chipped away with a chisel sufficiently to let in air, or, if all the vessels be ligated, the tourniquet may be removed carefully and slowly and the disarticulation be completed. The remaining vessels in the posterior aspect of the wound are now ligated; these are chiefly the branches of the sciatic, obturator, external and internal circumflex, and perforating. Having trimmed away all tags of tissue, the heavy muscles are to be quilted together with especial care, by means of two or three tiers of chromic gut sutures. Drainage is to be established. The margins of the wound are to be united in one continuous termino-external suture-line. Firm compression is made in dressing the wound, and the stump is supported upon a pillow.

By Anterior Racket Method.—The queue of the racket or oval is placed anteriorly, the limbs of the oval encircling the external, internal, and posterior surfaces. No tourniquet is used. The femoral is ligated during operation, and the remaining vessels as encountered.

The control of hemorrhage is as follows: utilizing the queue of the incision, the common femoral artery and vein are exposed and ligated during the progress of the operation. Other vessels are secured as exposed.

The patient is supine, lying at the end of the table, so that the pelvis rests upon the edge of the table and the hips project beyond. The limb is slightly abducted and rotated outward. The surgeon usually stands upon the outer side of both thighs. An assistant holds and manipulates the limb.

The landmarks are the center of Poupart's ligament and the course of the femoral artery.

The queue of the incision begins at the center of Poupart's ligament, passes down along the femoral artery for about 7.5 cm. (3 inches), thence curves inward and crosses the inner aspect of the thigh, about 10 cm. (4 inches) below the genitocrural fold, continues across the posterior aspect of the thigh, crosses the outer side of the limb a short distance below the base of the great trochanter, and then ascends upward and inward obliquely across the anterior aspect to join the vertical incision about 5 cm. (2 inches) below its commencement at Poupart's ligament (Fig. 378, B).

This incision passes well through the skin and fascia only, which are allowed fully to retract, and is made with several sweeps of the knife, while the limb is manipulated as indicated. Through the vertical portion of the racket incision the common femoral artery and vein are early exposed, and each ligated in two places and severed between the ligatures. The skin and fascia are fully freed around the entire incision without any special dissection. The muscles on the outer side (sartorius, rectus, and tensor vaginæ femoris) are divided and the external circumflex artery doubly ligated and severed. Passing backward,

rotate the thigh inward and cut the insertion of the gluteus maximus. Passing forward, rotate the thigh outward and cut the psoas, and retract the parts and doubly ligate and divide the internal circumflex artery. Divide the muscles of the internal flap on a level with the retracted skin (pectineus, gracilis, and adductors), ligating the muscular branches. Adduct and rotate the thigh inward, severing the muscles attached to the great trochanter. Adduct and rotate the thigh outward, cut the capsule transversely, disarticulate, sever the round ligament and the obturator externus tendon, if still undivided. The head of the bone is now drawn forward and outward, a long knife

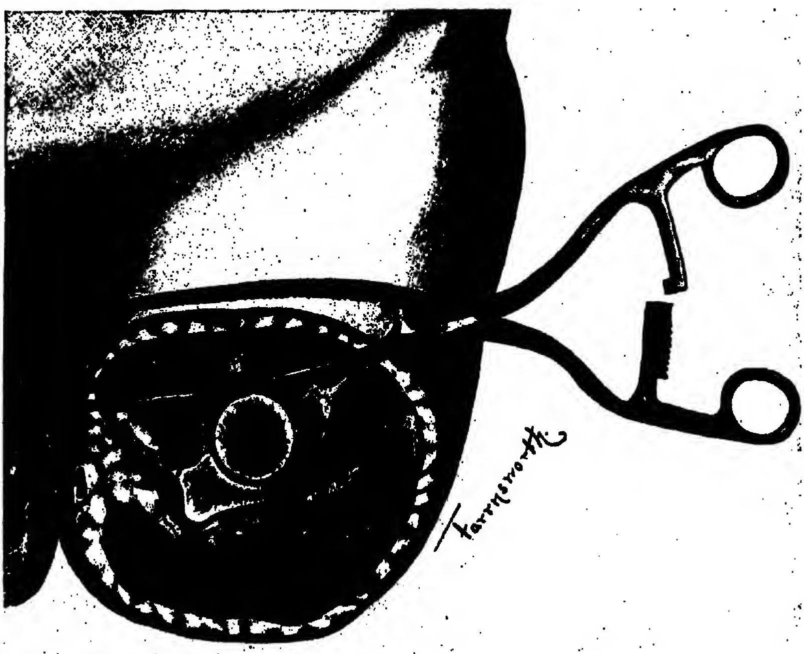


FIG. 384.—THOMAS' FORCEPS TOURNIQUET FOR CONTROLLING HEMORRHAGE DURING OPERATIONS UPON THE EXTREMITIES.

The probe-pointed blade passes under the femoral vessels, and the serrated blade over these structures, the former coming out through a previously cut exit, after which the blades are clamped.

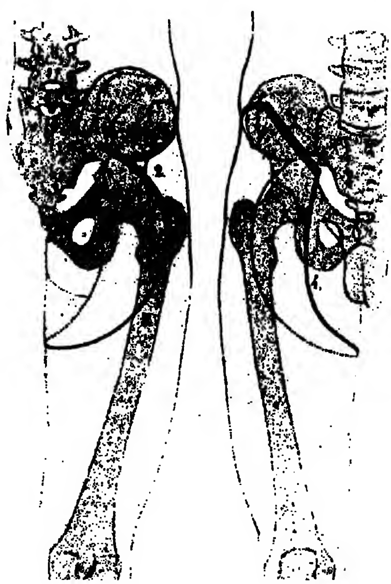
is carried behind the bone, passing downward and backward and dividing the remaining part at the posterior aspect on a level with the retracted skin (hamstrings, parts of the adductors and sciatic nerve), ligating the perforating and muscular branches. The muscles are quilted in two or three tiers, after having severed all tags of tissue and instituted drainage. The margins of the skin are sutured in a single vertical line. The stump is dressed as in the preceding operations.

Interilio-abdominal Amputation (*By an Internal Flap—Keen's Method*, Fig. 385).—This operation consists in the removal of the entire

lower extremity, with part or all of the innominate bone. It is indicated in extensive growths in the region of the hip-joint.

The patient is supine, with the hip-joint projecting over the end of the table, during the outlining and making of the internal flap, and is then turned toward the opposite during the exposure of the iliac portion of the wound. The landmarks are the spine of the pubis, Poupart's ligament, the crest of the ilium, and the posterior superior iliac spine.

The iliac incision extends from the spine of the pubis, 2 cm. (¾ inch) above and parallel with Poupart's ligament and the crest of the ilium, to about the middle of this crest. Subsequently, after ligating the internal iliac artery, this incision is continued around nearly to the



A B

Fig. 385.—Interilio-abdominal Amputation (Keen's Method). *A*, Rear view; *B*, front view. (Kocher.)

posterior superior iliac spine. The thigh incision begins just external to the middle of Poupart's ligament, and passes downward to a point a little below the middle of the thigh, then horizontally to the median line of the thigh posteriorly, and then upward to the posterior end of the first incision, *i. e.*, slightly external to the posterior superior iliac spine.

Having divided the skin, fascia, and muscles in the incision extending from the pubic spine, just above and parallel with Poupart's ligament and the iliac crest to about its middle, the internal iliac artery is exposed extraperitoneally. The long internal flap is now made. The incision is made just external to the center of Poupart's ligament, in order to preserve the femoral vessels, passing thence vertically down the

anterior aspect of the thigh to just below its middle, where it rounds horizontally outward to the midposterior aspect, and thence vertically upward to the posterior end of the horizontal incision. Having outlined this incision through skin and fascia, it is deepened to the bone. At the transversely divided muscles the femoral vessels are tied. This long internal flap, when turned upward and outward, will form the outer wall of the pelvis, and will be the barrier against intestinal hernia. The division of the muscles inserted into the crest of the ilium is now accomplished, having continued the first part of the iliac incision nearly to the posterior superior iliac spine, all the muscles of the anterior, lateral, and posterior abdominal wall lying beneath this incision are divided down to the peritoneum, the opening of which is carefully avoided. The psoas magnus and iliacus internus are now separated from the internal aspect of the ilium, to be left with the trunk. If they be involved in the tumor mass, they are to be sacrificed. Next follows the removal of the bone; the horizontal and descending rami of the pubic bone are divided, instead of disarticulated, at the symphysis. The attachment of the rectus abdominis is thus preserved, and consequently the firmness of support given thereby to the abdominal viscera. In order to preserve the sexual power in the male, the descending pubic ramus should be divided below the attachment of the corpus cavernosum of that side. Much time, difficulty, and hemorrhage are also saved in thus avoiding the separation of the rectus muscle and corpus cavernosum and the disarticulation at the symphysis pubis. The ilium is now divided posteriorly by sawing from the crest of the ilium, near its junction with the sacrum, down into the sacrosciatic notch. This avoids the difficulty and time involved in disarticulating at the sacro-iliac joint. If indicated, however, the small remaining portion of the ilium thus left attached could be removed after the removal of the main portion of bone, and this would also apply to the small part of the pubic bone at first left. The entire lower extremity now comes away with the detached ilium and the disarticulated hipjoint. The long internal flap is now brought upward and sutured so that its transversely divided end is applied to the iliac incision. The muscles are approximated by buried sutures, drainage is provided, and the skin closed. Pressure is made in the voluminous dressings, so as to sustain the weight of the heavy flap and exercise a supporting influence against the weakened pelvic wall.

FIG. 386.—INTERILIO-ABDOMINAL AMPUTATION. (KEEN'S CASE.)
The shaded portion of the bone was removed.

CHAPTER LXXVI.

PLASTIC OR RECONSTRUCTIVE SURGERY.

BY JOHN B. ROBERTS, M.D.,[1]

PHILADELPHIA.

HISTORY.

THE reconstruction of the contour of the body for cosmetic reasons, the readjustment of anomalous relations of parts for utilitarian purposes, the substitution of one tissue or organ for another to gain physiologic efficiency and the temporary removal or displacement of structures to permit operative attack on underlying structures constitute a special branch of surgical endeavor. To this department of operative surgery the term plastic has been applied. It is often equally well called reconstructive or reparative surgery.

In India the surgical restoration of the external nose, often cut off in that country as a punishment for supposed marital infidelity, has been a frequent operation for many centuries. Tagliacozzi, of Bologna, published in 1597 an illustrated volume describing his operative methods and successes in nasal and other reconstructions. For nearly two centuries this important surgical contribution of the Italian surgeon made little impression on the surgical world.

The revival of plastic surgery began in the middle of the eighteenth century, when Rosenstein and also Dubois and Boyer discussed the possibility of replacing lost structures by reparative operations. These writers proved that reconstructive surgery was possible, and secured historic evidence of noses and lips having been made from the tissues of forehead, arm, and buttock by Indian and Italian surgeons of previous centuries. Butler, in "Hudibras," and Dr. John Ferriar, in "Illustrations of Sterne with other Essays and Verses," published in 1798, called attention to the original observations of Tagliacozzi. About this time John Hunter's experimental work on grafting tissues was done. Just before Ferriar's forcible allusions to the brachial method of rhinoplasty there appeared in the Gentleman's Magazine for 1794 and in Pennant's Views of Hindustan accounts of the Indian method of making noses from the skin of the forehead. The Madras Gazette made similar statements at about the same date.

[1] It is a pleasure to acknowledge the assistance that I have had from Dr. Alexander R. Craig, Assistant Surgeon to the Methodist Hospital, in collecting material for this chapter.

These non-medical publications and the successful rhinoplasties of Lucas and Carpue in England, about 1816, and the work of C. Graefe, in Germany, finally convinced the surgical profession that success could be obtained. Balfour and Zeis showed that completely severed fingers and other portions of the human body could be reapplied to their original places and become reunited. In 1823 Bünger, of Marburg, repaired a nose with the tissues of the thigh. Hoffacker described, in 1828, instances in which portions of the face cut off in duels at Heidelberg had grown fast again after restitution to the original site. A little later Warren, of Boston, successfully transplanted small pieces of skin cut entirely free from the surrounding skin.

Toward the middle of the nineteenth century the interest in reparative surgery became very great. In Europe Dieffenbach, Graefe, Blandin, Roux, Serre, Jobert, and Zeis were its chief exponents; while in America its claims to consideration were urged by Warren, Mütter, and Pancoast, and later by Post, Buck, Andrews, and Prince. The terms autoplasty and anaplasty were suggested for this branch of operative surgery, but plastic surgery was finally quite commonly accepted.

In 1867 Szymanowski, of Russia, made an elaborate and successful attempt to systematize the principles upon which the various deformities of the contour of the human body could be remodeled by plastic operations.

Epidermic or "skin" grafting, proposed by Réverdin in 1871, the successful transplantation of severed pieces of skin, suggested by Wolfe and Krause, the use of skin shavings by Thiersch, the osteoplastic operations of Ollier and Lexer, and the success of Murphy, Payr, Hoepfner, Carrel, Garrè, and Guthrie in arterial suture and visceral transplantation, were further developments that widened the field of reparative and substitutive surgery. The aseptic healing of wounds, made usually possible by Lister's investigations, is the basis of this department of surgery. Thus were established as legitimate operative procedures tendon transplantation, muscle suture, nerve-grafting, arteriorrhaphy, arterial substitution, thyroid grafting, intestinal anastomosis, and osteoplastic resection and reconstruction. The transplantation of internal organs, blocks of varied tissues, and even of whole limbs, seems a possibility of human surgery.

The implantation of aseptic foreign bodies into the tissues with the purpose of leaving them there permanently was the next step in plastic surgery. Glass or gold globes introduced into the sclerotic coat as a substitute for the vitreous humor enable the ophthalmologist to maintain the shape of an eviscerated eyeball; metal or celluloid may be embedded to support parts or change the contour of the overlying skin; wire filagree or buried metal sutures may prevent the occurrence of hernia; celluloid masses may represent testicles, and rubber or other tissue is used to prevent adhesions of contiguous structures.

This "implantation therapy" is also the basis of Gersuny's idea of introducing melted, and therefore fluid, paraffin under the skin, by means of a hypodermic needle and syringe, and molding it into the desired shape before it hardens by cooling. This is a favorite treatment for remodeling "saddle" noses. It has been used to prevent inguinal hernia by making what might be called a "buried truss" in front of the internal inguinal ring.

GENERAL PRINCIPLES.

The surgeon resorts to plastic surgery to correct, for cosmetic or functional reasons, or both, congenital malformations and acquired deformities. Plastic surgery is also available when it becomes desirable to substitute, for physiologic reasons, one organ for another or to throw one organ out of active service. The rectum, for instance, may be made to receive the urine from the ureters in exstrophy of the bladder; or the stomach may be united to the jejunum, and, by this short circuit, the duodenum be excluded more or less completely from receiving the intestinal current. The spinal accessory or hypoglossal nerve may be united with the distal portion of a paralyzed facial nerve, to give motion to the muscular distribution of the latter. The femoral artery may be united to the femoral vein, so as to send arterial blood to a foot the subject of anemic gangrene, due to occlusion of the arterial branches of the femoral artery. The thyroid gland of a sheep may be transplanted into the body of a patient suffering from deficiency of the thyroid internal secretion; an ovary or kidney may be transplanted from the abdomen of one animal into that of another. These are good illustrations of the possibilities of substitutive plastic surgery. Of a similar character is the introduction of flaps of fascia between the ends of bones to cause the formation of new joints.

Plastic operations are often employed as a primary step to permit operative attack on deep structures or internal organs. A portion of the cranium with the overlying skin and muscle may be temporarily lifted, like a trap-door, on a hinge of soft tissues, in order to give access to the Gasserian ganglion; the costal cartilages may be divided in a similar manner and raised, in order to permit suture of the heart or to reach the lower part of the esophagus for surgical procedures thereon, and subsequently be replaced. These may be called "strategic" plastic operations, in contradistinction to those done for substitutive, functional, or cosmetic purposes.

As has been seen in the preceding paragraphs, plastic surgery has come gradually to include all surgical operations designed to modify the form of living structures. The alteration may be one of retrenchment or increase in bulk, or of change in mere relationship to surrounding parts. Originally living tissues only were employed in the constructive process. Now, however, inorganic materials, which become encysted in the tissues, are at times inserted to modify the shape or rigidity of structures.

The suffix "plasty" is added to the root of the Greek name of the organ repaired, in order to express the character of operation. Thus one speaks of a complete or partial rhinoplasty when the external nose is to be reconstructed; of cheiloplasty, meloplasty, or thoracoplasty when it is lip, cheek, or chest that is operated upon. If the tissues used in the plastic work are those of the patient himself, the operation is an autoplastic one; but if the grafts are taken from another human being or a lower animal, heteroplastic is the descriptive adjective used. Heteroplastic would seem to be a good term to employ also when inorganic materials are introduced, as in the so-called "implantation therapy."

Operators at first confined their attempts almost exclusively to the skin and subcutaneous cellular tissue. It only gradually became known that mucous membrane, fascia, muscle, bone, nerves, and even the internal organs could continue to live after being placed in new situations in the economy; and that even removal from one animal, human or brute, to another did not necessarily lead to death of the graft. It may be true that some structures, like muscle, become converted into fibrous tissue; but, on the other hand, nerves that have been cut or damaged regenerate, periosteum develops new bone, bone-grafts live and attain osseous union with neighboring bones, and large arteries and veins may not only be successfully sutured after complete division, but may actually be repaired by patching with a piece of another vascular canal. Carrel has exsected a piece of the carotid of a dog and successfully inserted it into the aorta of a cat, even after keeping it in cold storage at 0° to 1° C. for twenty days.

Since wounds of the lungs, liver, kidney, and other viscera heal, it seems not improbable that surgeons of the future may successfully graft into damaged viscera portions of healthy organs from other individuals, and that these may supplement the functions of the disordered viscus.

Christiani and Kummer report an instance in which, after excision of most of a goitrous thyroid gland, it was feared that not enough of the hypertrophied gland was left to prevent cachexia strumipriva. They, therefore, promptly planted small portions of the subject's thyroid gland, which were healthy, beneath the right acromion. The grafts not only lived, but increased in size. At the end of three years microscopic examination of one of these transplanted and growing thyroid organs revealed that it consisted of normal thyroid parenchyma. In other words, the healthy thyroid graft, taken from the goiter, produced a new thyroid gland in a novel situation. The value of such plastic operations may be inestimable in treating hypothyroidism.

A child with a cretin's brain, who had been treated for more than three years with tablets of thyroid gland, was recently treated by Payr, who implanted a graft of its mother's thyroid gland into its spleen. The mental condition of the patient, it is said, was improved. Kocher has advocated implanting pieces of thyroid gland and the

parathyroids into cavities previously prepared in the spongy portion of the tibia below the epiphyseal line. This region he calls the metaphysis.

Attempts have been made by Jaboulay to transplant the kidney of a pig and of a goat into the tissues at the bend of the elbow of the human subject. Two women with renal disease were thus treated. The transplanted kidney had its artery and vein united with the brachial artery and median cephalic vein respectively. The organs became gangrenous and had to be removed, but there was apparently evidence that some urine was secreted after the transplantation. Carrel has shown that an animal may be subjected to a double nephrectomy and have the kidneys of another animal of the same kind transplanted into its abdomen and live normally for a few weeks. Suprarenal bodies, parathyroid glands, and the spleen may be successfully transplanted. Knauer and Morris and Guthrie have proved the possibility of ovarian transplantation. In chickens ovarian transplantation has been followed by the production of eggs which were hatched. Similar results have been reported in the higher animals.

The vessels of a dog's heart, just removed from the animal, have been anastomosed by Carrel with the vessels in the neck of another dog, and the heart has resumed pulsation. Plastic surgery to effect the substitution of uninjured blood-vessels for damaged ones may be a means, in the near future, of saving limbs that would otherwise be amputated. It has been proved that veins may be used as arteries by anastomosing them with the cardiac portion of an arterial trunk. Carrel has grafted the amputated leg of a dog upon the stump left by cutting off the leg of another dog. The dog lived twenty-two days and died then of bronchopneumonia. The vessels were anastomosed perfectly, the skin was healed, and the bones were united by fibrous callus. It was too early to expect restoration of motion or sensation.

The same experimenter has successfully transplanted in a single mass the auricle, the external auditory canal, part of the scalp, the lymph-nodes in the neck, and parts of the common carotid artery, and the external jugular vein from one dog to another. The dog died after three weeks of pyemia, due to unsuccessful asepsis, but the anatomic region supplied by the carotid artery which was transplanted was united to the surrounding structures.

Krause recently attached the great toe of a man to the stump of his amputated thumb. The operation consisted in first resecting the head of the metatarsal bone of the toe. The back of the stump of the thumb was then made raw and applied to the base of the toe. The tendons and skin were carefully sutured, and the foot and hand held together for seventeen days with gypsum bandages. Then the plantar and palmar structures were divided and appropriately sutured after the toe had been disarticulated from the foot. The cicatricial tissue at the end of the thumb-stump was not made raw because it was desired to have also a joint there. The cosmetic effect was good, though the new thumb had little motion at the time of the report.

Lexer has successfully treated bony ankylosis of joints by resecting and inserting the joints taken from amputated limbs of other patients. Nails, wire, and bone pegs were used for fixation.

The physiologic basis of all plastic operations is the process of growth and repair in living tissues. This is supplemented by the ability of groups of animal cells to maintain their vitality for a short time, even when separated from all direct connection with the heart and the central nervous system. It is important, in the latter case, that no deleterious agents, such as bacteria or chemic irritants, deprive the protoplasm of the cells of its living power. Carrel has maintained the latent life in aseptic tissues for days, by keeping grafts in cold storage. Guthrie has written on the physiologic aspects of the surgery of blood-vessels.

When reconstructive operations are attempted by means of pedunculated, hinged, or displaced flaps, the blood and lymph circulation and the innervation to the transferred portion of tissue are maintained by the vessels and nerves in the pedicle or uncut portion. Its edges and surfaces then become united to the surrounding structures by exactly the same physiologic processes of outgrowth of vessels and nerves as are operative when an incised wound of skin, muscle, vessel, nerve, or bone heals. If the wound is aseptic, immediate or primary union is quickly effected by cellular and vascular activity. If it is contaminated with pyogenic micro-organisms, nature is compelled to combat the infective invasion by leukocytosis and the other general and the local processes, which constitute the complexus denominated inflammation. Under these circumstances the plastic operation may be jeopardized, delayed, or caused to fail utterly, by reason of suppuration, cicatricial contraction, or sloughing of the transferred flap.

It is easy to understand that flaps completely separated from their blood and nerve supply, before being transplanted to the new position, have a much less degree of individual vitality. They must depend for their nutritive supply upon the fluids and the metabolic energy within themselves until they have made a new physiologic connection with the cells in the structures, to which the operator has applied them. Hence it is that such plastic procedures require for success the most perfect asepsis and the most painstaking technic. Until a very recent time the success of plastic operations performed with skin, bone, or nerve completely detached from their original surroundings was denied. It has now, however, been demonstrated that there is little difficulty in such transplantations of animal tissues, provided that micro-organisms and chemical irritants be kept from the flap and the wound into which it is to be grafted. The reëstablishment of vascular circulation by anastomosis of blood-vessels is imperative in transplanting large masses, but is not necessary in operations of less magnitude. Surgical grafting is more difficult than budding or grafting in aboriculture, but the methods and processes are physiologically equivalent.

The size, vitality, and nutritive condition of the grafts have much influence on the result of such operations. Asepsis must be almost ideal, and the technical manipulation of the parts very skilful. Tendon-grafting is rarely successful, because the nutrition of tendon is not very great, and the grafts tend to become connective tissue. In muscle-grafting success is difficult of attainment unless the blood and nerve supply is carefully preserved. Bone-grafts, however, unite readily. Implantation of teeth was one of the earliest operations in this field to meet with success. Garrè, Carrel, and Guthrie have united arteries and veins without interfering with the circulation by causing thrombosis. Carrel has found that a graft of blood-vessel is converted into a tube chiefly of connective tissue, but it is living tissue, and may carry on its function as a blood canal for at least a year and a half. He has patched blood-vessels successfully with peritoneum.

In this connection it is interesting to speculate on the reason that organs do not regenerate in man and other animals of the higher vertebrate series. Blood-vessels, nerves, and skin regenerate in man, and so do bone and muscle to a certain extent, though perhaps less perfectly and less promptly than the other tissues just mentioned. It is due to this regenerative power that wounds heal and plastic surgery is possible. There apparently exists some connection between this regenerative process and growth; and yet man cannot reproduce his eye or a whole limb as do some of the lower vertebrates.

In fish the tail regenerates, and in some species this occurs even if the whole organ with the end of the spinal column is cut off. Fins will grow again if amputated. The tails and legs of salamanders and newts may be cut off repeatedly and will repeatedly reproduce themselves. Even the complicated organ of vision, the eye, will regenerate in the salamander if a piece of the optic bulb is left attached to the nerve. Tornier has produced an extra leg by cutting the skin, muscles, and bone near the attachment of the leg to the trunk. After regeneration of a cut-off leg has begun the new limb may be induced to develop two feet by constricting it longitudinally. In tadpoles similar changes may be produced by such injuries, so that four or six hind legs may be developed instead of the usual two. When a tadpole changes into a frog, the regenerative power of the hind legs is lost. Morgan, however, says that he has occasionally seen an adult frog regenerate imperfectly a foreleg. Lizards can reproduce the tail, but not the legs. In birds only the beak is reproduced if broken off; while in mammals no such regenerative power is found.

Morgan believes that the absence of this regeneration of lost organs in man is not due to the complexity of the structures, nor to a want of a process resulting from natural selection in vertebrates subjected to frequent injuries. He thinks it probable that man does not regenerate an arm or a leg, as do crabs and some of the vertebrates, because the tissues of man regenerate with different degrees of rapidity. The bones, which are most important elements in such reproduction,

regenerate very slowly, but blood-vessels, nerves, muscles, and skin reproduce themselves more rapidly. There is no tendency to synchronous regeneration of the necessary tissues. Hence a new organ cannot be replaced if it be once entirely lost. If a method of hurrying up the time of development of new bone is ever found, the regeneration of a limb in mammals may be near attainment, according to this author. Other causes of the loss of regenerative power in the higher animals may, of course, exist.

Successful plastic operations demand aseptic wounds, sound tissues, and good general health of the patient. Syphilis and lupus must be cured and new-growths removed before plastic restoration is attempted. Ingenuity on the part of the surgeon and patience on the part of the subject are prime factors in obtaining satisfactory results. Often only a bulky resemblance of the part to be reconstructed is obtained at the primary operation. Subsequent improvement is gained by a series of modifying procedures, which may require months for their accomplishment. The time allowed to elapse between the successive operations must be sufficient to permit all inflammatory reaction to subside, exudates to be absorbed, and cicatricial contraction to spend its force, in order that the surgeon may estimate what degree of modification is still necessary. It is important that too much should not be attempted at any one time, because death may occur from shock or bleeding.

The scars which necessarily result from plastic work should be placed in inconspicuous places, as in the normal wrinkles of the skin or parallel to them, in shadows, or in positions usually covered by the clothing or the hair. The elasticity of the skin permits such retraction that the incision may be placed at a point of election at a distance from the deep structures to be uncovered. Curved incisions make less conspicuous scars than straight cuts. Oblique division of the skin permits exact apposition and little noticeable scarring. The cuts should be made with sharp knives, and the sutures should be as fine as the estimated strain on them will permit. The material of the sutures is of little importance if it be aseptic and sufficiently flexible to permit accurate adjustment of tissues. The subcuticular, or intracutaneous, suture may at times be useful. Pins should seldom, if ever, be used. The edges of wounds may be made to pout or to sink in by properly inserted sutures. Tension on the skin may be distributed by judicious suturing. It should be remembered that scars made in childhood increase with growth of the patient to adult life. Scars of wounds, although healed by first intention, may increase considerably in width subsequent to union, if considerable tension was required to draw the wound-edges together. The wound does not reopen, but the scar stretches. If cavities, such as the mouth, vagina, or nose, are involved in the operation, it is wise to place one set of sutures on the mucous surface of the wound and another on the cutaneous surface; and thus prevent infecting secretions from reaching the suture tracks on the skin side, unless it be desirable to allow the

mucous side of the wound to gape for drainage. If the tension put on the lips of a wound by the sutures or by cicatricial contraction tends to drag structures, such as the eyelid, out of position, the sutures must be changed, so that the closure of the wound will cause no dragging. Sutures crossing a wound obliquely may be used to distribute tension to various areas of skin.

The chief causes of failure in well-planned plastic work are suppuration and gangrene. As living tissues are the basis of this department of surgical art, every effort must be made to maintain their cellular vitality. Tight sutures do harm in this regard. Reparations are made largely by the use of flaps or grafts of soft tissues. A "flap" has an attachment to the adjacent tissues and receives its blood and nerve supply therefrom. A "graft" or "free flap" is entirely separated from its surroundings, and is much more likely to die than a flap which has a pedicle. It is often necessary that the tissue used to close a gap should be of the same structure and of the same texture and color as the part to be repaired. This point may determine whether a graft or an attached flap is to be employed. Grafts may be required because it may be impossible to obtain a flap with a pedicle. Grafts are seldom employed except to close small gaps, because of the greater likelihood of necrosis occurring in them. An exception is in skin-grafting, where many shavings or fragments of skin of moderate size are laid upon ulcers or wounds. If asepsis is obtained and maintained, these shavings of skin retain their vitality. Cutaneous flaps with pedicles will not be apt to retain vitality unless made of healthy skin with a considerable amount of subcutaneous cellular tissue, and with a pedicle broad enough to carry a satisfactory blood and nerve supply. Grafts, however, should be free from cellular tissue, and are probably better when their larger vessels are free from blood. Scar tissue is not vascular enough to be used for flaps, and scar tissue in the pedicle or at the edge of flaps is a serious detriment. Sloughing of such flaps is almost certain. For a like reason a flap should not be expected to fill a gap in cicatricial skin, because the surrounding tissue is not vascular enough to supply sufficient blood to cause union between the flap and the margins of the gap, and thus prevent sloughing of the flap. It is better to trim away the cicatricial fibrous tissue and interpolate a larger flap, which then becomes rapidly adherent to, and vascularized by, its surroundings, which send vascular and nervous outshoots into it.

The part to which the flap is to be applied should be vivified by paring away skin, mucous membrane, or cicatricial tissue. The gap will become larger than might be supposed because its edges retract. The flap itself, if a cutaneous one, will shrink about one-third of its area. It should, therefore, be made one-third larger than the space to be covered. The flap should not be cut until the space to be repaired has been made raw, and the bleeding from its vessels arrested. The pedicle should contain the chief vessels and nerves, if possible, and should not be tightly stretched or sharply twisted, lest gangrene

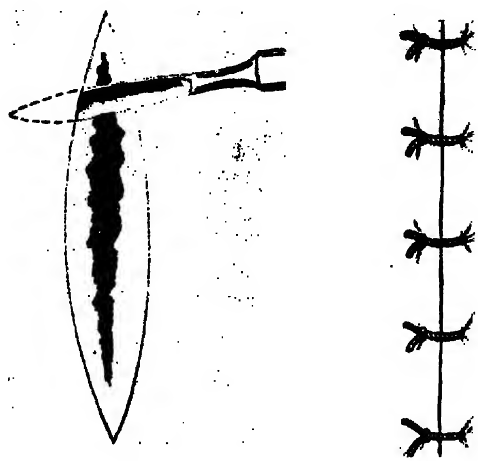
follow the pressure thus caused on the arteries and veins. The contact of the flap with the underlying raw surface and the edges should be close, so that new capillary loops may rapidly develop between the two portions of living tissue. Such contact is secured by equable pressure of the dressing aiding the sutures. The edges of the flap may be beveled to make a wider surface of contact. It is well to have the flaps emptied of blood, since blood remaining in the vessels is liable to clot and prevent the early resumption of circulation. This is the reason for the well-known fact that a pale, anemic flap is less likely to slough than a congested one. In the former it takes but a few hours for blood flow to be reëstablished in the vessels. As few moments as possible should elapse between the cutting of a flap or graft and its adaptation to its new position. If any delay occur, the flap or graft should be kept heated to about 105° F. This may be accomplished by wrapping it in gauze soaked in warm sterile salt solution, or immersing it in such a solution. The experiments of Carrel with grafts kept in cold storage seem to negative this opinion. After the new tissue has been placed in position, it should be covered with sterile rubber tissue or oiled silk and firmly dressed with sterile gauze. A dry dressing is usually better than moist. Moderate heat may be maintained with advantage for a few hours by applying hot-water bags outside of the dressing. If a flap free from hair cannot be obtained, the hair-follicles may be destroyed by electrolysis or the *x*-ray after it has united. Hairy flaps are needed in constructing eyebrows.

If no evidence of necrosis is seen in four days, there is not much likelihood of its occurrence. If the flap becomes gray and pulpy, moist gangrene is present, and the dying tissues should be cut away or sterilized. If this be not done, the whole field of operation may become infected, because this form of gangrene in plastic surgery usually means bacterial contamination of the wound. A flap congested from venous engorgement may be saved by punctures, to drain out the blood, before gangrene has started. A dry and black condition of the transferred tissue means that anemic gangrene has taken place from insufficient arterial supply. This process does not spread beyond the part immediately affected. The black, mummified tissue should not be hastily removed, for often the process is very limited. It may only involve part of the thickness, or the mere edges or end of the flap. The operation may not be much imperiled by its local occurrence. The application of dry heat outside of the dressing may dilate capillaries and lessen the extent of anemic gangrene.

Sensation returns slowly to the transferred tissue. For a time it feels numb and cold. The patient often feels in it the sensations belonging to it when in its original site.

METHODS.

The constructive material is applied to either a fresh wound or a granulating surface. In the latter case the surface is generally scraped or in some way made raw, to hasten the development of a bond of capillary loops between the applied surfaces. The methods



A B

FIG. 387.—OPERATION FOR DEPRESSED SCAR.

A illustrates lines of incision around depressed scar, and knife separating skin from underlying tissue. B, edges sutured after being drawn to middle line over depressed tissues which have been made raw by scraping.

may be classed under four heads: (1) Displacement; (2) interpolation; (3) retrenchment; (4) implantation.

Displacement is attained by simply stretching the tissues and approximating the edges, or by detaching them from the underlying

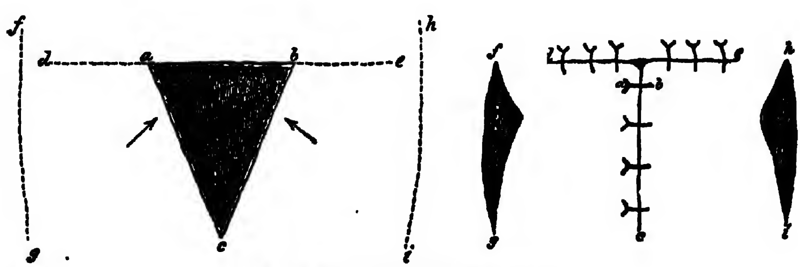


FIG. 388.—RELAXATION INCISIONS.

fascia and muscles and then sliding them into a new position. The undermining or undercutting needed may be quite extensive. The degree of sliding and transference of tension in this method may be increased by relaxation incisions parallel to the original incisions.

Interpolation consists in borrowing tissue and inserting it into a gap to be filled. The borrowed portion may be taken from an adjacent region or a distant part of the patient, or from another animal, human or brute. Under certain circumstances the tissue to be transferred or transplanted may be obtained from a body just dead or from a limb just amputated from a living patient.

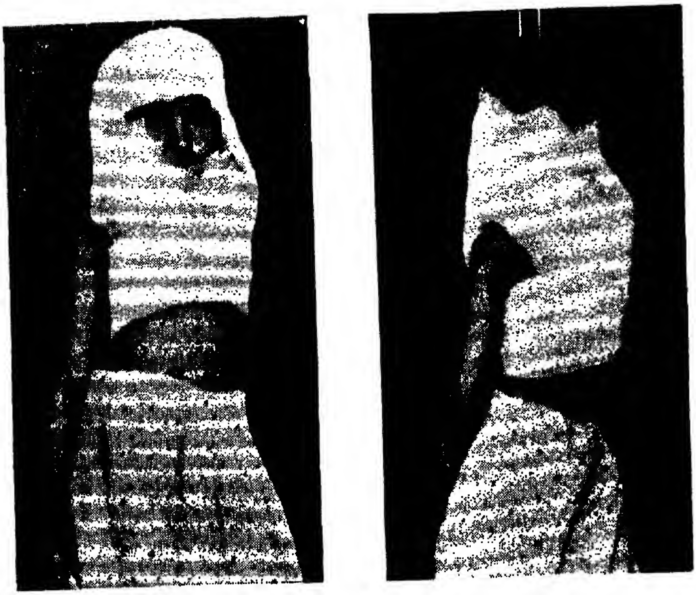
The interpolated tissue or flap may depend for vitality upon a pedicle connecting it with the general circulation and innervation of the donor. This pedicle may connect it with surrounding tissues, or with a limb, which is held by bandages near the region to be repaired by the flap. Sometimes the flap is cut in the shape of a bridge and

FIG. 389.—A PEDUNCULATED FLAP.

Skin-grafting and flap from back tacked to cranium. The tacks had been removed, because of adhesion of flap, before photograph was taken. Scalp torn off by machinery some six months previously.

has two pedicles. Instead of a pediculated flap, a "free" flap or "graft," which is entirely separated from the donor, may be transplanted. Occasionally it is necessary to use a double transfer. In this method a flap is first transferred to the hand from the abdomen of leg, for example. After it has grown fast to the hand, it is cut loose from the abdomen or leg and sutured to the face, by bandaging the hand and arm close to the head. When the end of the flap has grown fast to the face, its attachment to the hand is severed. The hand is thus used as a medium of transportation to avoid irksome or impracticable restraint when obtaining a pediculated flap from a distant part of the patient's body.

The pediculated flap method has a great range of applicability.



A B

FIG. 390.—GYPSUM BANDAGE APPLIED TO KEEP ARM TO FACE IN MAKING LOWER LIP FROM TISSUES OF ARM.
A, front view; B, back view.

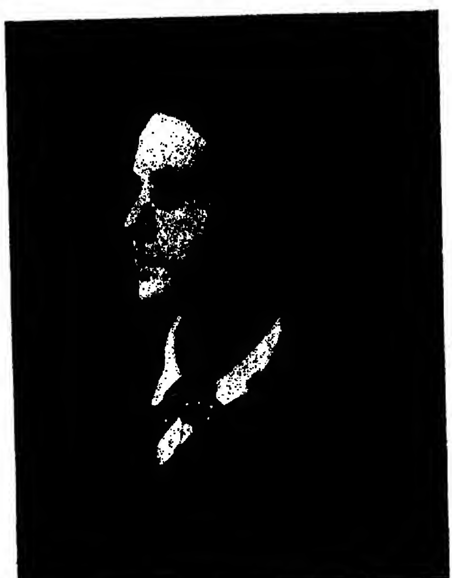


FIG. 391.—TUMOR ON CHEEK REMOVED AND GAP FILLED WITH FLAP FROM SHOULDER. (Beatson.)

Flaps may be made of various shapes and sizes, and several may be employed in a single operation. They may be rotated or twisted into position, everted or inverted so as to place the raw surface where it

is desired, superimposed one upon another, thrust through a button-hole incision in the skin, stitched into a tubular shape, doubled upon themselves, and made to migrate from place to place by successive plastic procedures. It is only necessary to see that these manipulations do not constrict the vessels in the pedicle and cause gangrene. Sometimes a flap with a broad base may be split into two or more finger-like prolongations. If it be of advantage, a flap may be split parallel to its surface, and the superficial portion used as a graft to cover a raw surface elsewhere, while the deeper layers of the skin fill

FIG. 392.—A TOE FASTENED TO HAND AND THEN TRANSPLANTED TO NOSE IN A RHINOPLASTIC OPERATION. (Kausch.)

the gap needing repair. In rare instances the flap is made and surrounded for a few days with aseptic rubber tissue and gauze, to prevent readhesion to its bed; it is transferred to the new site only after it has become thickened by inflammatory processes. Such secondary flap operations are not often used at the present time. The degree of rotation and twisting of the pedicle permissible may be increased by making the sides of the flap curved and prolonging the incision on one side. The twist should then be made from the long edge.

Transplanting free flaps or grafts is a valuable method of interpolation that has recently come much into vogue. It is especially used in covering with skin-grafts raw surfaces left after operations or granulating ulcers the result of sloughing subsequent to burns. The

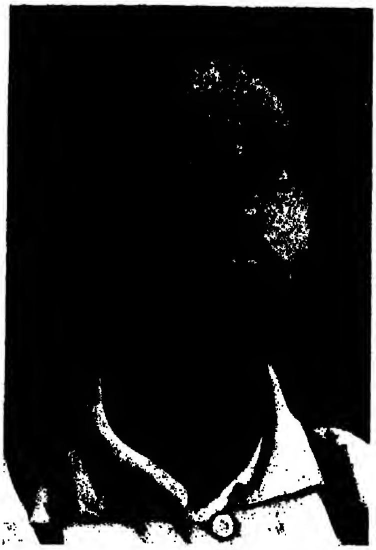


FIG. 393.—ROTATED FLAP FROM CHEEK TO REPAIR ALA OF NOSE.

grafts are usually taken from the abdomen or limbs, and, therefore, the scarring caused by cutting the grafts is hidden by the clothing. Bone-grafts for closing trephine holes in the cranium, omental grafts for patching the hollow abdominal organs, and tubular grafts to

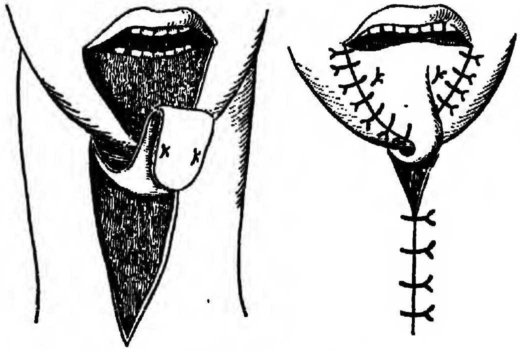


FIG. 394.—A TWISTED FLAP.

reconstruct the urethra are illustrations of this method. Nerves and blood-vessels are repaired by such a grafting process. The graft is sometimes stitched into its new position; at other times it is laid in position and adheres by plastic exudation. Such

grafts may be cut from another individual, who should be free from any disease. Grafts from the lower animals are occasionally used. Nerve-grafts, vascular grafts, urethral grafts, glandular grafts, and bone-grafts are thus obtained. Dupraz has used successfully, it is stated, skin-grafts taken from an amputated leg nine hours after

FIG. 395.—SUPERIMPOSED FLAPS.

operation. Skin from recent cadavers has been used. Many hours may elapse without interfering with successful grafting from cadavers, if the dead body is kept cooled to the freezing-point. Lexer has used pieces of bone from the epiphysis of the knee of amputated legs for

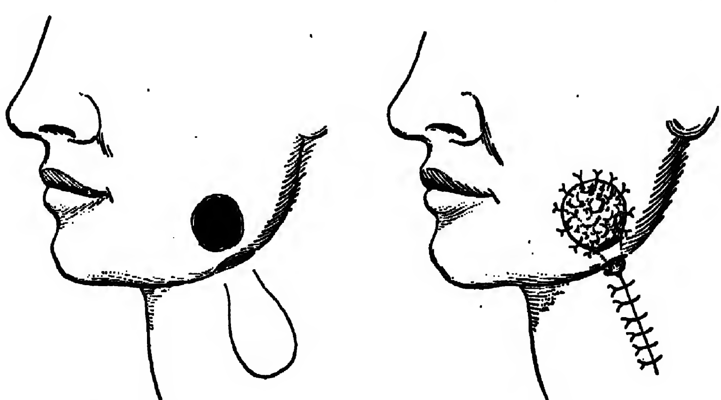


FIG. 396.—FLAP THRUST THROUGH BUTTONHOLE TO CLOSE OPENING IN CHEEK. Skin shavings may be put over external surface, which is raw.

closing openings in the skull. He has recently been successful in transplanting whole joints and even half joints, from the same source, into patients who have lost by operation the articular ends of the long bones. Bone-grafts may be similarly used to raise sunken places in the face, to complete defects in long bones and the mandible, and

to cure false joints. Paralytic joints may be stiffened by pegging, and other operations on the skeleton be done by utilizing free bone-grafts.

Retrenchment is used in plastic surgery to diminish size, to remove superfluous material, and to cause cicatricial contraction. Its object may be to alter the relative proportion of parts for cosmetic or mechanical reasons.

The insertion of aseptic inorganic materials into the tissues with the intention of having them become permanently encysted is a recent development of surgery. Enthesis has been proposed as a name for this implantation procedure.

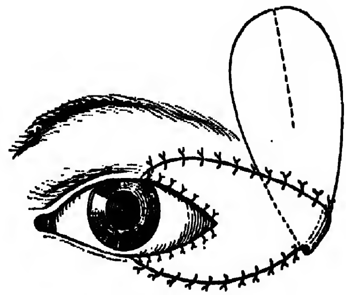


Fig. 397.—Split Flap.

Metal plates, wire, screws, nails, celluloid, rubber tissue, and paraffin are the substances usually employed. Paraffin is frequently used in a hot fluid condition. After it has been injected into the subcutaneous structures it cools, hardens, and maintains the shape given to it while warm by pressure of the fingers. Its chief use is in changing the contour of sunken noses. Embolism of the central artery of the retina, with consequent blindness, has occasionally followed the hypodermic use of hot paraffin. Hence some operators now use it in the cold state. It may be mixed with rubber. The technic of paraffin prosthesis is described in the chapter on Diseases

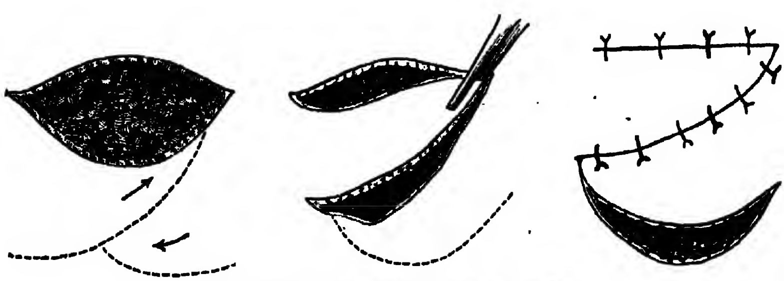


Fig. 398.—Flap with Curved Margins.

of the Nose. Solid foreign bodies employed by enthesis are introduced through appropriate incisions.

Plastic reconstructions often demand a combination of osteoplasty, tenoplasty, angeioplasty, and neuroplasty, as well as dermatoplasty or skin-grafting. Delicacy of manipulation, asepsis, the use of normal salt solution instead of antiseptic solutions, and artistic ingenuity will often give success that astonishes even the operator himself.

SKIN-GRAFTING; MUCOUS MEMBRANE GRAFTING.

Plastic operations involving tendons and muscles, nerves, bones, blood-vessels, and the omentum and other viscera are described in the appropriate chapters.

Skin-grafting, that is, the interpolation of pieces of skin without a pedicle, is performed in three ways: the Réverdin method, the Thiersch method, and the Wolfe or Krause method. In the first, very small particles of the epidermis with the underlying upper layer of the derm are transplanted; in the second, long strips or shavings of the same material are used; in the third, pieces of the entire thickness of the skin, several square inches in size, are transplanted upon the raw bed. The first two might with propriety perhaps be called epidermatoplasty, the last, dermatoplasty.

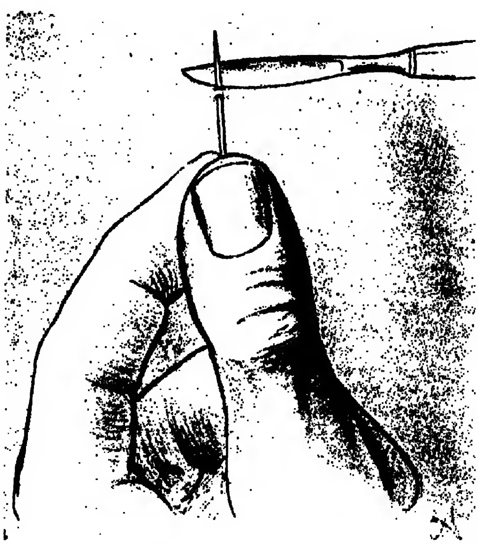


FIG. 399.—TECHNIC OF USING THE NEEDLE AND SCALPEL FOR CUTTING MINUTE SKIN-GRAFTS.

In all these procedures the raw or granulating surface is made sterile and bathed with warm sterile salt solution. In the case of granulating ulcers a sterile surface may be obtained by dressing the part for several days with a formaldehyd solution (1 : 200). The hardened surface of the granulations thus caused is to be scraped off, when the grafts are to be applied. It is well to shave off the tops of the granulations with a sharp knife or razor, which makes a smoother surface than the curette. Bleeding is stopped by pressure with an aseptic pad of gauze, and the grafts are then applied. The skin of the front or inside of the thigh or arm is usually selected for grafts. It is elastic and not apt to be hairy. It should be sterilized and then bathed with sterile salt solution. Réverdin grafts should be two or three millimeters long. They are readily cut by thrusting the

point of an aseptic needle under the epidermis and putting the skin on the stretch by lifting the needle. A minute fragment of skin is then excised with a sharp knife or scissors. Dozens of such grafts, obtained in this almost bloodless and nearly painless way, are placed, with the epidermic side upward, on the raw surface or granulating ulcer. Some operators make small punctures into the granulations and press the grafts into these depressions. Rubber tissue or Lister protective is laid over the grafts to prevent their displacement, and a dry aseptic dressing is applied and left undisturbed for four or five days. These little grafts at first shed their cuticle and become almost invisible; but a few days later bluish-white spots of cicatricial skin are seen where the grafts have begun to grow. These islands grow in extent, and apparently stimulate the edges of the wound or ulcer to similar activity. After a time the islands of cutification coalesce and join with the margin, and the whole space is converted into scar tissue.

FIG. 400.—RÉVERDIN SKIN-GRAFTING IN TRAUMATIC ULCER OF THE SCALP. (Levis.)

Thiersch grafts are cut by means of a razor. This should be wet with sterile salt solution and may perhaps be greased with sterile oil to make the thin shaving of epidermis and true skin slide over its surface more readily. The skin, also moistened with salt solution, is put on the stretch with the fingers or hooks. The operator then cuts numerous shavings about one-half inch wide and four inches long. The shavings involve only the most superficial layers of the true skin with the corresponding epidermis. These strips are laid on the raw surface, leaving no intervals between them. The raw surfaces of the wound or vivified granulations and the grafts adhere, and no sutures are needed to keep the grafts in place. Rubber tissue is laid over the grafts to prevent their displacement, and a dry gauze dressing is firmly applied, so as to press the grafts against the raw surface. It is left undisturbed for five or six days. Some operators prefer an aseptic moist dressing, kept constantly wet. Gaps may be left between the strips of rubber tissue to allow escape of serous transudate or blood; but in the Thiersch method the grafts should lie close together. It is usually necessary to anesthetize a patient from whom many of these grafts are taken.

Local infiltration anesthesia may be used, according to J. D. Bryant. Very large ulcers and wounds are quickly healed by this method. It is especially valuable in causing rapid cicatrizations of large ulcers following burns. The grafts should be applied in such cases as soon as the

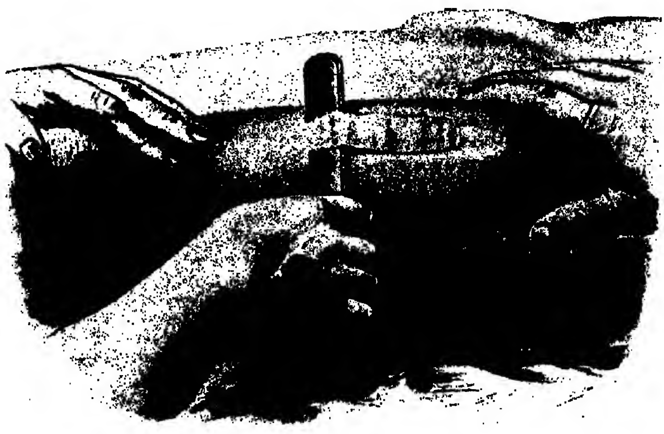


FIG. 401.—THIERSCH METHOD OF SKIN-GRAFTING. (Marwedel.)

sloughs have separated and the surface can be made sterile. Delay allows cicatricial contraction to become increasingly great, as the granulations are converted into fibrous tissue. The immediate union between the grafts and the vivified granulation surface tends to obviate

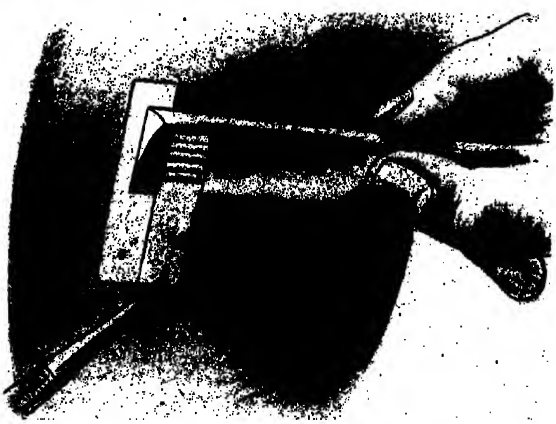


FIG. 402.—PUTTING GRAFTS IN POSITION.

much of the disfigurement likely to occur from vicious cicatricial contraction. Thiersch believes it necessary to remove the surface of the granulation before planting the grafts, if the further scar contraction is to be successfully avoided. It is said to be well to also remove the cicatricial edge which has usually formed around the margins of ulcers.

This bluish edge has been dissected up, cut into pieces, and used for skin-grafting. Instead of covering the grafts with rubber tissue or protective silk, a piece of sterile tulle may be laid over them. This may be made with wide meshes, and be rendered non-absorbent by filling the threads with sterile paraffin. The gauze dressing is applied over this retentive fabric, which is left in place for ten or twelve days. Two parallel incisions made part way through the skin, before it is put on the stretch for cutting the grafts, may be of assistance in obtaining long and even grafts. Pressure on the skin with a hard substance in advance of the razor may facilitate the little operation.

The Thiersch method is very valuable. It does not make a deep wound where the grafts are cut, and enables large surfaces to heal rapidly. The cicatrix so obtained sometimes ulcerates easily. Keetley says that a valuable use of the method is to line deep aseptic bone cavities. The cavities fill up by tissue developing under the grafts.

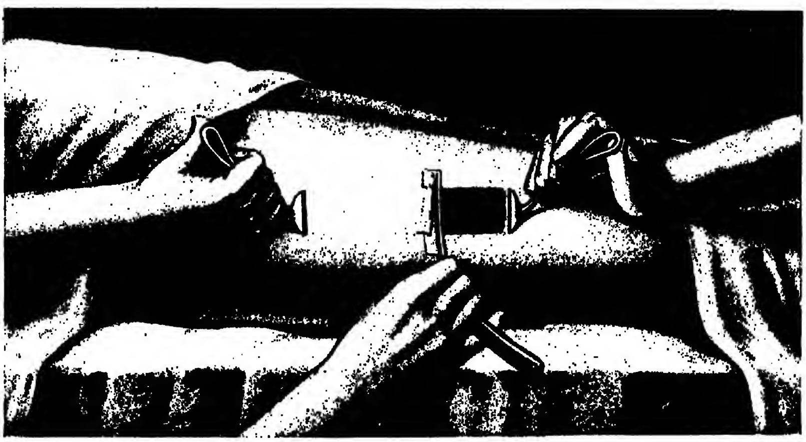


FIG. 403.—CUTTING A SKIN-GRAFT. (Fowler.)

In treating cicatrized burns by this method he first dissects out all the scar tissue. He believes that epitheliomatous, tuberculous, and other ulcerations, which have been excised, show less tendency than usual to recurrence, if Thiersch grafts are used to fill the gap in the soft tissues.

Wolfe or Krause grafts consist of the entire thickness of the skin, and must be free from subcutaneous fatty tissue. The circumference of the free flap to be cut is marked by an incision through the skin. An end is then seized with toothed forceps and raised, so that the operator is able to dissect it free from the superficial fascia. The knife used should be sharp and its edge should be turned toward the skin, in order to avoid raising some of the subcutaneous fatty tissue with the skin. The raw surface should not be touched with the fingers and the operation should be dry. The graft may be obtained by dissecting up skin and subcutaneous fat from the deep fascia, and then clipping all the fat away from the under surface with scissors. This method leaves a wound easily closed after undercutting its margins. The graft is

carefully laid in the bed that has been aseptically prepared, and is pressed into place so as to drive out any air beneath it. Sutures may or may not be used. Dry dressings are to be firmly applied and should not be removed for about four days. Then there may be blebs on the surface, and it may look as if necrosis of the flap was about to occur. The blebs should be punctured and drained and dry dressings reapplied. Krause flaps may be laid upon bone, muscle, fascia, or other structures. They will usually live, if a dry aseptic technic has been carefully carried out, even if they are several square inches in area. Motion of the parts, to which the grafts have been applied, should be prevented by means of splints, whenever necessary. Hairy grafts may be employed to replace eyebrows.

Mucous membranes may be repaired by pediculated flaps of mucous membrane, by grafts of mucous membrane, or by using skin-flaps or grafts. Skin thus transferred or transplanted becomes converted into a pseudomucous membrane, when continuously subjected to the moisture of cavities lined with mucous membrane. Defects in mucous membrane of the urethra, eye, and mouth have been repaired by mucous membrane grafts from man and the lower animals. Skin-flaps with pedicles of subcutaneous tissue only have been employed for such purposes, and have been thrust through slits or buttonholes in the skin of the cheek and elsewhere. If mucous membrane is used, the entire thickness must be employed. The difficulty of maintaining asepsis and immobility of the parts makes mucous membrane grafting less successful than skin-grafting. Pediculated flaps of mucous membrane are therefore more reliable.

CICATRICIAL DEFORMITIES OF THE SKIN.

Cicatricial contraction subsequent to sloughing from burns and scalds often causes frightful deformity of the face and limbs. The contraction is lessened if the ulcers, left by the separation of the sloughs, are quickly healed by means of skin-grafting. The Thiersch and Krause methods are to be employed. They should be resorted to as soon as a clean granulating surface has been obtained. Wilcox obtains, in such infected ulcers, an aseptic surface by first washing with green soap and solution of hydrogen dioxid. If the ulcer be very foul, he applies a compress wet with a 50 per cent. solution of hydrogen dioxid for several days. The surface cleansed by either of these methods is then covered with a compress moistened with a 1 per cent. solution of formaldehyd for eight or ten hours. This changes the upper portion of the granulations into a dry, leathery tissue. This layer is removed by a sharp instrument, and the bleeding stopped by equable pressure of a rubber bandage, applied for a few minutes. To the aseptic bloodless surface thus obtained the grafts are applied. A weaker solution of formaldehyd applied to ulcers for a few days answers equally well.

When distortion has already occurred by ulceration having healed more or less completely, the surgeon must divide the scar tissue to

permit readjustment of the displaced structures. It sometimes is necessary to dissect out the entire scar until normal tissue is reached.

FIG. 404.—DEFORMITY FROM BURNS OF THE HANDS. (Keen.)

In either case plastic operations are then performed to fill the gap and transfer the tension to areas where it will do no harm. Unless the

FIG. 405.—DISFIGUREMENT FROM BURNS.
Improved by incising scar tissue under chin and taking two long flaps from back which were brought around the front of the neck like a cravat.

distortion is remedied, joints may become permanently immovable or dislocated, bones bent out of shape, orifices, such as the nostrils, closed,

FIG. 406.—DEFORMITY OF MOUTH AND ARMS FROM BURNS. (Spellissy.)

FIG. 407.—FLAPS FROM BACK TO RELIEVE DEFORMITY SHOWN IN FIG. 406. (Spellissy.)

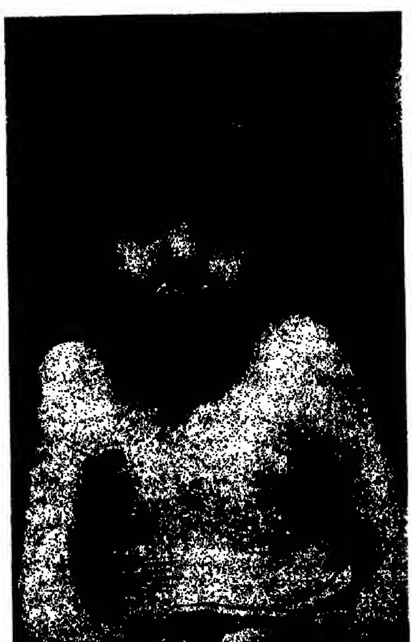


FIG. 408.—RESULT AFTER OPERATION ON CASE SHOWN IN FIG. 406. (Spellissy.)

lips and eyelids everted, arms fixed to the chest by folds and bands of scar tissue, and the hands converted into mere claws.

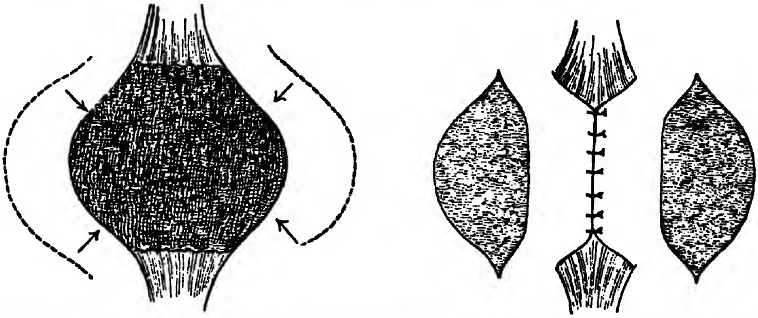


FIG. 409.—MASON'S OPERATION ON CICATRICIAL DEFORMITY OF CHIN AND NECK DUE TO BURNS. The scar tissue was divided, the chin lifted and the edges of skin dissected up and united in the middle of the gap. (Mason.)

The methods already described for plastic reconstruction must be employed to remedy these distortions from scars. It is impossible to describe formal operations, because the deformities vary greatly in

FIG. 410.—FLAP FROM OPPOSITE LEG TO GRAFT ULCERATED SPACE.

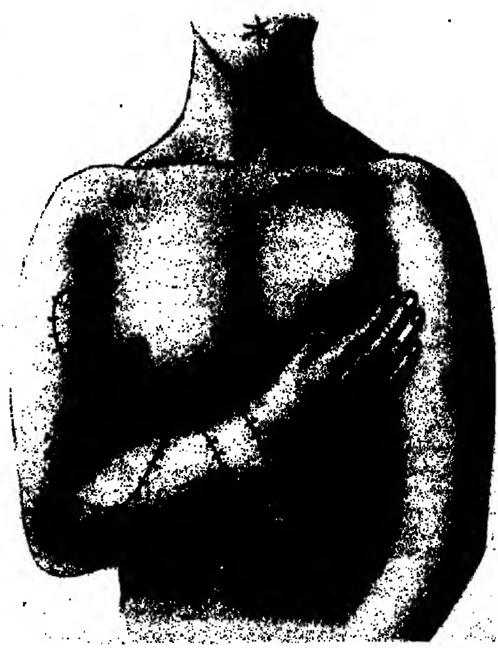


FIG. 411.—1, THORACIC FLAP TO FILL BEND OF ELBOW; 2, FLAP WITH DOUBLE PEDICLE FOR FOREARM TAKEN FROM ABDOMEN; 3, FLAP TO ARM.

kind and degree. The operator must select his method, after a study of the particular problem. A series of operations extending over many months is often required. Frictions with oils, such as adeps lanæ,

massage, and patient stretching may aid the operative treatment. Thiosinnamin and other caustic applications may be used to smooth down rough and nodular scars. The x-ray will lessen the irregularities.

A few illustrations will show the general methods more quickly than written descriptions.

The manner of performing plastic operations will be understood by examining the illustrations of operations for harelip, cleft palate, ectropion of the eyelids, exstrophy of the bladder, resections of bones, osteoplastic amputation of the extremities, and deformities of the nose and face in the appropriate chapters of this and other volumes.

RHINOPLASTY.

Rhinoplasty, which includes all operative repairs of the external nose, is resorted to in partial or complete congenital absence of the organ, and is employed to repair losses of its tissue from any cause and to modify deformities in size or shape, whether congenital or acquired.

A very common congenital defect of the external nose is the flattening of the wing and broadening of the nostril occurring in connection with harelip and cleft palate. This deformity should be corrected by early operation upon the palate and lip, combined with readjustment of the alar cartilage.

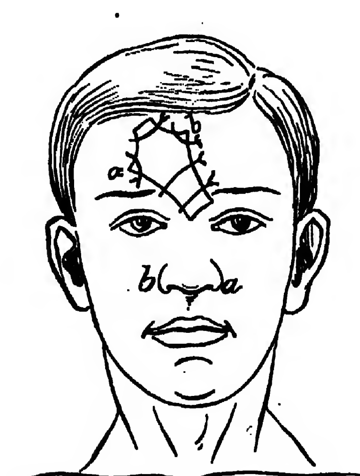


FIG. 412.—DIAGRAM OF FLAP AND METHOD OF SUTURING EDGES OF FRONTAL WOUND IN D. F. KEEGAN'S METHOD OF RHINOPLASTY. (Modified slightly from Keegan's illustration.)

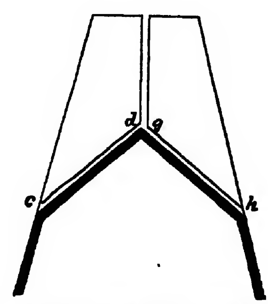


FIG. 413.—KEEGAN'S OPERATION.

Diagram showing outlines of flaps of skin and fascia overlying the bony nasal bridge. These are turned downward as on hinges between c and d and g and h. Thus the skin surface is next to the nasal cavity and a raw surface is created from the nasofrontal suture to the end of the nose. This is then covered with a frontal flap (Keegan).

The chief difficulties in extensive nasal reconstructions are the production and maintenance of sufficient projection from the surface of the face, the formation of nostrils, which will remain patent, and the construction of a columella which post-operative contraction cannot distort. Many nasal deformities liable to cause much mental distress may be avoided by the early recognition of syphilitic lesions, followed by prompt and efficient specific treatment.

Deformities of the nose and interference with proper respiration through the nasal chambers would be greatly lessened in frequency if, after injuries to the face of seeming unimportance, patients were carefully examined for fractures and dislocations of the bones and cartilages of the nose. This applies particularly to the nasal injuries occurring in childhood.

Prosthetic appliances fitted to the face to remedy defects in the nose do not come under rhinoplastic surgery, unless they are buried in the tissues to be permanently retained there.

In rhinoplastic operations pedunculated flaps may be taken from the arm, forehead, or cheeks. Brachial flaps require the upper extremity and head to be held in apposition by some form of retentive apparatus for from ten days to two weeks. The flap taken from the upper forearm

FIG. 414.—FRONTAL RHINOPLASTY FOR REPAIR OF THE CUT-OFF CARTILAGINOUS EXTERNAL NOSE.
Photograph taken on sixteenth day after Keegan's operation. (Keegan.)

or hand may sometimes be permitted with advantage to undergo contraction from partial cicatrization, and be molded somewhat into shape before the head and arm are approximated and the flap sutured in the nasal region.

Lexer * has ingeniously cut a piece of the condyle of the femur, taken from an amputated leg, into the shape of a nose, bored holes into it for nostrils, and planted this bony mass under the skin of the forearm. Three months later, when the bony nose had become adherent to the skin and underlying muscles, he transplanted the whole mass upon the face.

Frontal flaps have the advantage that there is no restraint in the patient's posture during treatment and that portions of periosteum or bone may be cut from the forehead and embedded in the newly made

* Verhandl. der Deutsch. Gesell. f. Chirurgie, 1908, ii.

nose. Scarring of the forehead may be a good deal lessened by plastic closure of the wound and skin-grafting.

Pedunculated flaps from the cheek are not often used in total rhinoplasty, but are employed in partial reconstructions of the external nose. It may be necessary in nasal reparations to use superimposed flaps from the forehead, the cheek and arm, in order to obtain necessary thickness and rigidity for the new organ. Free flaps, or grafts, of skin may be successfully utilized. Portions of cartilage taken from the ribs or ear, or from recently dead tissues of men or lower animals may be planted in the soft tissues to give the requisite rigidity. In the same way strips of bone or periosteum from the forehead, tibia, ulna, ilium, finger, or toe, or from the lower animals have been implanted. Modification

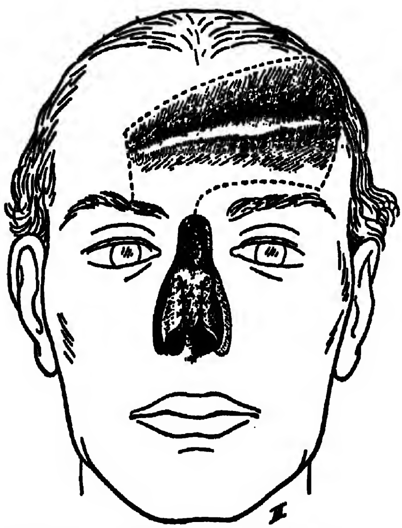


FIG. 415.—CHARLES NÉLATON'S OPERATION FOR COMPLETE LOSS OF NOSE.

A, The nasal flaps have been inverted and sutured, the fragment of costal cartilage has been inserted under the periosteum, and the proposed frontal flap is indicated by a broken line. (Nélaton and Ombrédanne.)

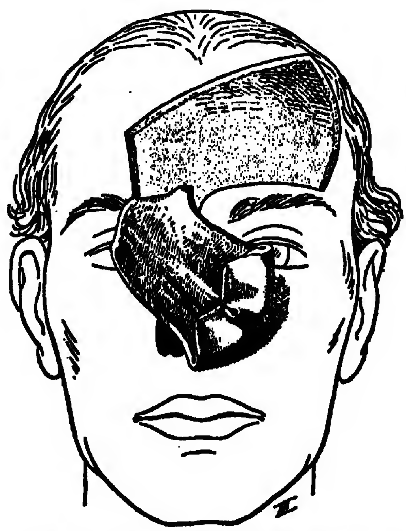


FIG. 416.—CHARLES NÉLATON'S OPERATION FOR COMPLETE LOSS OF NOSE.

B, Eversion and molding of the frontal flap containing the piece of costal cartilage. (Nélaton and Ombrédanne.)

in shape is sometimes obtained by resort to subcutaneous injections of paraffin or paraffin mixed with other materials.

When the external nose has been removed by sharp instruments, leaving the nasal bones intact, the method of Keegan is probably the best for a rhinoplastic reconstruction. In this operation two cutaneous flaps are dissected from the surface of the nasal bones and turned downward upon a cutaneous hinge just above the lower border of the bony bridge. These flaps then cover the opening into the nasal chambers, with the skin surface inward and the raw surface presenting outward. As a result of this manœuvre the raw surface extends from the frontonasal junction downward and forward to the proposed tip of the new nose (Figs. 412 and 413).

The operator then cuts an oblique frontal flap with its pedicle near the inner canthus of one eye. This flap should be so cut as to make provision for the alæ and columella of the new nose. The frontal flap, after being raised, is twisted on its pedicle and laid with its raw surface against the raw surface previously made by turning down the flaps from the nasal bones. The projection on this flap intended for the new columella is fitted into a pocket made above the middle of the lower lip, and the incisions at the side of the nasal region are deepened and lengthened to receive the edges of the flap from the forehead. The frontal wound is closed with sutures and skin-grafts, and drainage-tubes are kept in the nostrils for a few days. The pedicle near the corner of the eye is divided, and the tissues readjusted at that point at the end of ten or fourteen days.

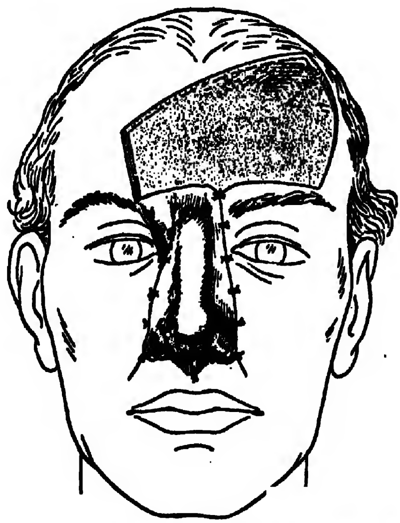


FIG. 417.—CHARLES NÉLATON'S OPERATION FOR COMPLETE LOSS OF NOSE.
C, The frontal flap sutured in position so as to form nares and columella as well as the nasal bridge. (Nélaton and Ombrédanne.)

Instead of trimming away the rather voluminous median margins of the two flaps turned down from the nasal bones, Henry Smith inverts these median edges into the nasal cavity and thrusts them into a split made in the remains of the septal cartilage. This makes a new septum and lines almost the entire interior of the new nose with skin (Fig. 414).

Charles Nélaton recommends a more elaborate method of performing total rhinoplasty. The first step consists in excising almost the whole length of the costal cartilage of the eighth rib. He trims this structure down to a thickness of about 3 mm. along about 2½ cm. of its length. At a point where he expects to bend this strip of cartilage to make the point of the nose he cuts a notch. The prepared cartilaginous support for the dorsum and columella is then thrust into a horizontal tunnel made between frontal bone and its periosteum. The cartilage becomes connected with the surrounding tissues in about two

months. At this time the cicatricial edges of the stump of the nose are pared loose, making three flaps. The superior flap is turned downward; the lateral flaps are turned inward, and they are sutured together so as to close to a greater or less extent the opening into the nasal chambers, which has been left by the loss of the external nose (Figs. 415–417).

The next stage in the operation is to cut from the forehead an irregularly quadrilateral flap having its pedicle near the inner border of the right eyebrow. This flap contains the transplanted costal cartilage lying longitudinally in its middle. When the flap is raised from the bone, the entire periosteum with the implanted costal cartilage is taken. The surgeon twists this flap downward, bends the contained cartilage, and fixes the frontal structures on top of the nasal flaps

FIG. 418.—CHARLES NÉLATON'S OPERATION FOR SUBTOTAL LOSS OF THE NOSE.
Diagram showing outline of flap used. (Nélaton and Ombrédanne.)

FIG. 419.—CHARLES NÉLATON'S OPERATION FOR SUBTOTAL LOSS OF THE NOSE.
Cutting the bony roof for the new nose from the frontal bone. (Nélaton and Ombrédanne.)

which have been made from the margins of the nasal opening. A fair and rigid substitute for a nose is constructed. The frontal wound is closed by skin-grafts and usually heals without very much scarring, even though a thin layer of bone may be lost by necrosis due to the removal of the periosteum.

Brachial rhinoplasty is at the present time not considered so available for replacing totally lost noses as it is for filling gaps after the loss of a part of the nose only. Sometimes a pedunculated flap from the chest or the abdomen is attached to the arm or hand, and is subsequently cut from the trunk, and then applied to the nasal region. Occasionally operators have employed both frontal and brachial flaps, superimposing one upon the other. Flaps from the cheeks may, in the same way, be used in connection with frontal and brachial flaps.

The operative devices for meeting the requirements of partial rhinoplasties are innumerable.

For subtotal loss of the nose Nélaton saws a long A-shaped flap from the forehead and nasal regions with a thin saw. This flap contains a plate of bone from the forehead and portions of the nasal and superior maxillary bones. This osteoplastic flap is slipped downward, and, being flexible, can be bent into shape and sutured so as to make a fair substitution for a nose (Figs. 418–421).

Very pronounced instances of saddle-nose may be remedied more or less satisfactorily by splitting off pieces of bone from the lateral margins of the nasal opening in the skull by means of a chisel. These are to be loosened above and pressed toward the middle line, con-

FIG. 420.—CHARLES NÉLATON'S OPERATION FOR SUBTOTAL LOSS OF THE NOSE.)

The bony roof and flap of soft tissues displaced downward previous to the application of the sutures. (Nélaton and Ombrédanne.)

FIG. 421.—CHARLES NÉLATON'S OPERATION FOR SUBTOTAL LOSS OF THE NOSE.

Appearance of patient after the sutures have been inserted and tied. (Nélaton and Ombrédanne.)

stituting thereby a nasal bridge. The new position occupied by these pieces of bone may be secured by transfixing the nose under them with a steel pin.

Syphilitic sunken noses with old inflammatory adhesions between the skin and the internal structures require very radical operative procedures. There is usually a sharply defined transverse groove just above the middle of the sunken area, and the cutaneous structures are usually very fibrous from cicatricial changes. The distressing deformity so caused may sometimes be improved by separating the skin of the nose from the nasal bones by an inverted U incision. A frontal flap, perhaps containing periosteum or bone, should then be turned down and tucked under the first flap. A fragment of bone, cartilage, or periosteum may be incorporated in this reparative work. Occasionally undermining

the skin with a tenotome and injecting semisolid paraffin or paraffin liquefied by heat may relieve the deformity.

These operations, however, will not always restore the normal position of the tip of the nose, which needs to be drawn down so that the plane of the nostrils shall be horizontal, as in the normal nose. The sunken nose of syphilis, as also the undeveloped saddle-nose, has a tilted-up lobule which makes the opening of the nostril lie in an almost vertical plane. To correct this deformity is an important preliminary step in relieving the disfigurement of both these conditions. It is particularly essential in the sunken nose of syphilis. The first step, there-

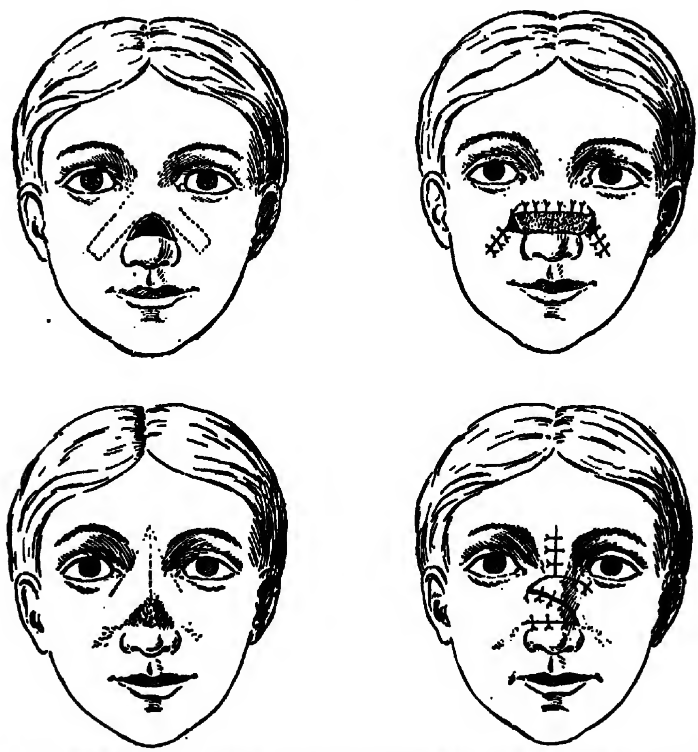


FIG. 422.—ROBERTS' METHOD OF MAKING NASAL BRIDGE WITH CHEEK FLAPS AND RHOMBOIDAL FLAPS FROM FOREHEAD.

fore, in correcting a badly sunken nose is to make a transverse incision in the transverse groove at the bottom of the sunken region. This cut must go into the nasal cavity and permit the operator to draw down the lobule and the alæ until the prominence of the tip is restored and the nostrils again lie in the horizontal plane. The huge opening in the nasal chambers, between the bony bridge above and the replaced lobule and alæ below, must be closed by tissues which will be permanently thick and rigid. Some years ago I devised a method which answers well for this purpose. The first step is to cut a flap from each cheek near the nasolabial furrow. These are turned upward and

inward and sutured in the middle line with the skin surface toward the nasal cavity. The raw surfaces present forward. After these flaps have become united and are more or less cicatrized, the irregularities at their base are corrected by incisions and sutures (Fig. 422).

The next step is to make an inverted V incision, beginning in the middle of the forehead. The legs of this incision run downward and outward to the points on the cheeks below the eyes. Just above the united flaps, turned in from the cheeks, a similar inverted V-shaped cut is made. The second incision has its legs more widely separated than the first.

A vertical incision in the middle line of the nose joins the apices of these two V's. By these cuts the surgeon has made two rhomboidal flaps with their pedicles on the cheeks close to the sides of the nose.

Fig. 423.—End of Nose Destroyed by Caustic Before Operation.

Fig. 424.—Appearance of Patient Shown in Fig. 423 After Operations to Build up Lobe of Nose from Cheeks.

A dissection down to the bone lifts these flaps, and they are turned downward over the cicatricial or granulating surface of the reversed cheek-flaps. The upper angle of the right flap is sutured to the base of the left ala, and that of the left flap is turned across the nose so as to reach to a point near the inner canthus of the right eye. The frontal wound is quite easily closed in a vertical direction. The rigidity of these tissues placed between the root of the nose and its lobule is sufficient to prevent the flaps being sucked in by the pressure of the atmosphere during inspiration.

The reduction of an exceedingly large nose may be accomplished by an operation devised by Joseph. The width of the organ and the big nostrils are lessened by cutting out an A-shaped portion of the skin and cartilage on the anterolateral surface of the nose. The bones and cartilages forming the roof or dorsum are then pared away with chisel

and scalpel; and, finally, the nasal septum is shortened by cutting out a wedge with its base forward and its point directed downward and backward. Joseph reports that his patient, who had formerly been very unhappy, was greatly pleased with the change, which converted his large nose into one of moderate size.

For restoring the alæ or the lobule of the nose pedunculated flaps may be taken from the cheeks, lip, or chin, or the surgeon may use the brachial method.

The new alæ may be lined with mucous membrane dissected from the nasal septum, or repaired with a flap from the cheek with the skin surface turned inward. The prevention of cicatricial obstruction of the nares makes the construction of new alæ very troublesome. Thiersch grafts of skin may be used to cover the raw surface of a flap before it is put in position to make an ala. Small skin-flaps may perhaps be thrust with success through buttonholes in the skin to line a new ala. To stiffen an ala so that it will not collapse during inspiration the operator may possibly slip a piece of cartilage, taken from the ear or costal cartilage, into the tissues used for making the wing of the nose. A columella which lacks rigidity, because made of soft tissues or because of congenital absence of cartilage, may be stiffened by thrusting a peg of cartilage, cut from the tip of the eighth costal cartilage, obliquely backward and inward through a tunnel made with a tenotome. This procedure is used to hold the lobule forward and stiffen the lower portion of the septum.

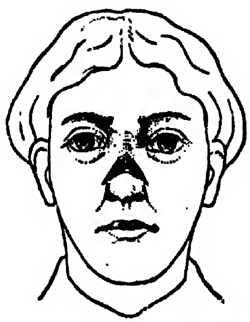


Fig. 425.—Sunken Nose Drawn Down after Transverse Incision.

A columella lost from ulceration or other cause may be constructed from two vertical flaps cut from the upper lip, one of which is taken from each side of the median line. These need not go through the entire thickness of the upper lip. A single median flap may be used for the same purpose. A portion of the nasal spine of the upper jaw may be chiseled loose and turned upward to give rigidity to a new columella which the surgeon is about to make.

Bent and twisted noses of various forms may be much improved by a thorough division of bones and cartilages, and loosening the attached soft parts subcutaneously with a tenotome, and twisting back the structures into a better anatomic relation. It is wise to overcorrect such deformities. The new relations must be maintained for about ten days or two weeks by the use of nasal pins or intranasal splints.

Noses the site of rhinoscleroma or of chronic rosaceous hypertrophy may be restored to a normal size and shape by simply shaving off the excess and allowing cicatrization to take place, with or without skin-grafting.

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CHAPTER LXXVII.

SURGERY OF ACCIDENTS.

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One can scarcely wonder that accidents are increasing almost from year to year when he takes into consideration the increase in rapid locomotion of many kinds and the multiplying factories, workshops, mines, and quarries all over the country.

While the *ratio* of accidents compared with the number of employés is apparently not increasing,[1,2] the total *number* of accidents is increasing every year. The number of mine accidents seems not to be increasing relatively.[3,4] Accidents on the railroads, however, do seem to be steadily increasing.[5]

The report of the Interstate Commerce Commission[5,6] shows that the largest number of deaths from railroad accidents are among the class which is called in railroad reports "trespassers." In 1904 there were 10,046 fatalities from railroad accidents. Of these, 3632 were employés, 441 were passengers, and 5973 were "other persons." Of these so-called "other persons'' who were killed, 5105, over 85 per cent., were reported "trespassers." Grade-crossings are responsible for most of the casualities of so-called "trespassers." Accidents occurring to employés and passengers result, for the most part, from carelessness or neglect on the part of the individual injured or of some employé responsible for the safety of others.

The statement has been frequently made, and it is commonly supposed, that coal-mining is the most hazardous of all employments. The report of the Department of Labor No. 32, p. 18, shows specifically that this is not true. The report states: "It is a matter of interest to note that coal-mining is a less dangerous industry than that of railway transportation. While in the latter 1 switchman, flagman, etc., out of every 195, and 1 trainman out of every 150, were killed during the year 1898, in coal mines the proportion was only 1 out of every 347 employés in anthracite mines, and 1 out of every 443 in bituminous coal mines, in Pennsylvania, 1 out of 467 in Illinois mines, and 1 out of every 720 (year 1897) in Ohio mines."

While undoubtedly the nature of the employment, the surroundings, and the method of conducting the work will determine the number of injuries, there can be no doubt that the actual number of fatal cases resulting from injuries will be very greatly lessened by prompt and

skilful treatment. Nearly every large mining company has a select, well-equipped, and competent surgical staff, either in actual employment, or it has a special arrangement with an independent hospital in the immediate neighborhood. Injured men, therefore, receive prompt and competent attention. There are certain conditions of environment, which will be noticed later on, which make wounds in mines somewhat less dangerous than similar injuries above ground; these, however, will hardly explain the fact that nearly four times as many railroad men as miners die from their injuries. I believe that the lack of proper first-aid appliances and a proper surgical organization on most railroads in the United States (those of the East are especially lacking) are to a very great extent responsible for this increased loss of life. For instance, in a number of instances I have known of men with crushed extremities being transported long distances on the railroad without any appliance or care to prevent hemorrhage; and I know a number of men have lost their lives because this neglect resulted in their bleeding to death. In a great many instances I have known men to be transported long distances on dirty stretchers in dirty cars, through dirty baggage-rooms, without any protection for an open wound, or, what is worse, in a great many instances I have known badly soiled bandages, waste, etc., applied as dressings to open wounds. Better the open air than dirty rags. It is not too much to say that hundreds of men injured on the railroad every year die from pure neglect. These are unnecessary deaths. Railroads should be obliged by law to make provision for properly caring for their injured employés and passengers.

This can be properly done only by establishing, in connection with a thoroughly organized surgical staff, a system of first aid, which has done so much to lessen the mortality in war. It is obviously impracticable for a competent surgeon to be delegated to every train on the railroad, but it *is* possible for every road to have its responsible employés systematically taught the elementary principles of first aid to the injured, especially the vital importance of controlling hemorrhage and the prevention of soiling of a fresh wound. Besides, every railroad should be required to carry first-aid packets and an accident package on every train, and more should be placed at every station along the line. These accident packages should each contain two rubber tourniquets, a package of aseptic gauze, a package of absorbent cotton, a half-dozen muslin bandages of various widths, zinc oxid adhesive plaster, and a bottle of antiseptic tablets. Forceps, scissors, needles, and aseptic ligatures might be added for the use of the surgeon. That a system of this kind may be efficient I have had abundant reason to know, for in 1886, while I was chief surgeon of a railroad line, I had this system established. For the six years after its introduction the record of accidents showed that the mortality-rate was 50 per cent. lower than the preceding six years

ORGANIZATION OF SURGICAL STAFFS OF RAILROADS.

The organization of the surgical staff on a railroad must be varied somewhat according to the line or system concerned. For example, it would be out of place, on a line which traverses a thickly populated country, with numerous large towns, each with a well-equipped hospital and a skilful surgical staff, to have exactly the same organization as a line traversing a sparsely settled country.

One officer, however, should be common to all, namely a chief surgeon. He should combine the skill of an experienced surgeon with fine executive abilities. To him should be delegated the whole responsibility of the surgical affairs of the road. If the road be a large "system," there should be division surgeons—one for every 200 or 250 miles of road. These should report to the chief surgeon and be answerable to him alone. There should also be local surgeons at suitable intervals. These should report to the division surgeons and be answerable to them.

The chief surgeon should have an office, properly equipped, with an adequate clerical force, centrally located. He should be regarded and be paid as one of the chief officers of the road. He must give his whole time to the road.

The division surgeons should have offices near the division superintendents, but should not be under them or report to them. They ought to be paid for the work actually done for the road at their regular rates. It will not be necessary for them to give all their time to the affairs of the road.

The local surgeons should be selected from the most competent men of their several localities. They should be paid regular rates for their service and never by any contract rate or by a stated salary. As to passes or transportation over the road, the company ought, of course, to furnish transportation, either by pass or by mileage, to all the surgeons who travel in the discharge of their duties as railroad surgeons, and to the annual meetings, but they ought to pay for themselves and their families when they travel on their own affairs or for pleasure.

The duties of the several surgical positions are indicated in their respective names. The chief surgeon should organize, inaugurate, and conduct all the sanitary and surgical affairs of the road. He should be to the railroad what the surgeon-general is to the army.

The division surgeons should be responsible under the chief surgeon and answerable to him for the sanitary and surgical affairs of their respective divisions.

The local surgeons, selected from the best qualified men of their localities, and distributed every ten or twelve miles along the road when this is practicable, should have a definite territory assigned to each one, say, five or six miles of road on either side of his residential town; or certain localities, *e. g.*, the shops, switchyards, or stations, if they are located in a city. They should render prompt first aid to any person injured on the road within their territory, and should determine in ordi-

nary cases and circumstances the further disposition of the injured person, that is, whether he should be treated at his home or be sent to a hospital. They should immediately make carefully written notes of the circumstances of the accident and the exact nature of the injury, its extent, prognosis, and its initial treatment, and forward these data to the division surgeon.

Local surgeons should go to any reasonable distance along the line outside of their individual territories in case of a serious wreck or catastrophe along the line. In cases of large wrecks, where many or several surgeons are at work, the division surgeon should be present, if practicable, and direct the work. If this is not practicable, the local surgeons present should elect one of their number as acting chief, and the one thus selected should direct the measures of surgical relief. In big wrecks it is always best to conduct the surgical work something after the military method—*e. g.*, a field-hospital should at once be established as the base, in a neighboring house, if possible, or under an improvised shed. Ordinary day coaches are usually very inconvenient, and are always infected. Except in case of a large new Pullman, they should be used only after the dressings have been finished. In the chief dressing station, if practicable, three surgeons should be stationed, with all the accumulated dressing materials and improvised splints, etc. These surgeons should see to it that clean water, a fire, and disinfectants are provided. The other surgeons should be sent in pairs to rescue the wounded, make immediate provision for their needs, and send them at once to the main dressing station, which I have called the field-hospital, for proper first dressing.

When all the injured have been dressed, Pullman cars, if available, may be utilized for the comfort and transportation of the patients, or the ordinary day coaches may be utilized for beds by turning the backs of the seats alternately, removing the cushioned seats, and laying them longitudinally from one seat to the other of the turned sections. This will convert every two sections into one section for the wounded to lie on. When there are so many injured that all the space must be used, after turning the backs of the seats to face one another, the two double seats may be removed and be put longitudinally across the frames. This, however, makes a much less secure and comfortable bed than the plan first suggested.

If the road has one or more hospital cars, and it is practicable to get them to the scene of wreck, these, of course, would serve as the chief dressing station, and would furnish comfortable quarters for a few of the seriously injured, besides adding most materially to the facilities for caring for the injured.

HOSPITAL CARS ON RAILROADS.

Railroad surgeons have been discussing for a number of years whether it would aid the surgical organization on a railroad line, and especially whether efficient prompt surgical aid might better be rendered by a system of hospital cars on each road. This question of hospital

cars on the lines in America is *sui generis*. We cannot use the fact that Germany and Belgium have found them useful as a convincing argument in favor of them for American lines, because the lines are so much longer and are so differently managed in this country.

Expense.—A very important matter will be the expense. At a low estimate, $15,000 would be required to build and equip each car. The cost of running and transporting the cars over the line would be a very considerable expense every year.

Range of Efficiency.—Recently, in speaking to an experienced dispatcher about this matter, in answer to the question, "Under ordinary conditions on a busy railroad line, how fast time could you guarantee a hospital car in moving from one point to another?" he replied, "twenty-five miles an hour would be about the limit." As a means of rendering first aid, therefore, a hospital car would be too slow to be efficient in a great many, perhaps the majority of, instances.

Location of the Car and the Number Required on a Line.—Under ordinary conditions, then, twenty-five miles an hour would be the expectation of hospital-car service. This might be in two directions, of course, and so make the range of one car fifty miles. In order, therefore, to assure a service of one hour from the time of its call, there must be one car for every fifty miles of track. When there are a number of lines branching out from a common center, the proper location of the car would naturally be at the center or point of convergence of the lines. One car in such conditions might serve a much larger territory. Under the ordinary conditions of trunk lines, however, one car for every fifty miles would be necessary to give service with any degree of promptitude. For a main line of 500 to 800 miles ten to sixteen cars would be necessary. Then there would be yards and branches to be cared for. These would require for a 500 or 800 miles' system the addition of five or six cars—a total of fifteen to twenty-two hospital cars. Yards, reshipping points, crossings, junctions, and termini are generally regarded as especially liable to accidents. Wreck cars are, as a rule, not evenly distributed over a line. It would doubtless be well to follow this rule with hospital cars. Perhaps a hospital car might be located with every wreck train. About ten wreck cars are allowed to a road of 500 miles of main track. To follow this last suggestion would provide about the same number of hospital cars as the first plan of distribution required. Putting them with the wreck cars would assure more prompt service in case of serious catastrophes, perhaps; it would delay them, however, in many other instances. They would have to be uncoupled and detached from the wreck train when the hospital car alone was required.

Surgical Service on Hospital Cars.—If the cars are to be properly efficient, a surgeon or surgeons must accompany them on all their expeditions of mercy. To assure this it would be necessary to recast the ordinary arrangement of local surgeons along a railroad. It might be made a rule that the surgeon in whose territory the accident occurred should serve on the car. In the east, however, it is rare for one local

surgeon to have charge of a territory of twenty-five miles of road. He might render first aid and then turn the patients over to the next local surgeon upon reaching his territory, so that in a transportation of twenty-five miles two surgeons might have to officiate. It is rare, on most roads, to find in every section of twenty-five miles a hospital or place of permanent treatment to which the injured person could be carried. The journey of the car, therefore, would have to be much longer in some instances. The first surgeon to render aid would have to go far afield and leave his location for many hours perhaps, or else there would be a large number of changes of surgeons en route. This would, of course, in the last instance, work no end of confusion. Suppose, however, the rule was made that the first local surgeon to render aid must accompany the patient to his destination. The time this would require would be a very serious matter to a surgeon unless there was a proper pecuniary return for his work and time. Grant, however, that the railroad company would pay for the surgeon's time and work. If it were at the usual rate of fees, very few railroads would stand it. This service, to be efficient, would require salaried surgeons, and the expense would be very heavy if the men employed were properly qualified. I believe no railroad would stand such expense.

Another arrangement might be made, and in some instances would not prove inhuman nor hurtful, viz., a local surgeon might render first aid, and then intrust the injured person on his further journey to a lay employé—brakeman, flagman, or conductor. Some one ought to remain in the car with the patient, surely. If it be a lay employé, he must give up his other occupation during this time. This, if frequently required, might also make a serious expense, and in a great many instances be inexpedient and dangerous.

Again, if the car has to leave its own territory, as it must do in order to prevent the evil of transshipment and very serious discomfort to the injured, what provision shall be made for caring for possible accidents during its absence? It would not do for the next car on the line to take its place, as this would only transfer the evil. It is obvious, therefore, that a hospital car must be supplemented by other provisions for caring for injured persons.

If the foregoing points are well taken, it is obvious that in order to equip a railroad line, which has a main line of as many as 500 miles, with hospital cars in sufficient number to begin to do efficient service in the majority of emergencies, would cost from $200,000 to $300,000; the maintenance and running of these cars would also add materially to the annual expense account. The personal and usual arrangement with local surgeons would have to be materially changed. Lastly and especially, prompt and rapid first aid by means of hospital cars, under ordinary conditions, could not be rendered in a large number of individual emergencies. No doubt the sentimental value of a system of hospital cars for emergency work would be very considerable, but one cannot advocate any such system when there are other more prompt and efficient means of succor.

The argument that a hospital car furnishes seclusion, comparative comfort, and facilities for proper dressings, and even operating-room facilities, is frequently used. I am willing to grant the first point, without argument, provided the car is at once available. I think I have shown, however, that in many instances this will be utterly impracticable. The value of the other points of the argument, I think, is very doubtful. We know it is much more important that the man who does the first-aid dressing shall have had the proper training and experience and know the best modern way of handling injuries, than that all proper facilities for applying dressings shall be provided to a less competent man. As I have said, in writing upon the "Treatment of Compound and Complicated Fractures,"[7] the fate of the injured person depends very greatly upon the man who does the first dressing. It is certainly not best for a seriously injured person to be put in the hands of an inexperienced and poorly trained man, even if he has all the facilities for doing first-rate permanent work. The inexperienced man will be thus encouraged to attempt dressings which are intended to be final in compound fractures, very severe lacerations, or avulsions. Very rarely, except in minor or the most urgent cases, ought operations to be attempted in hospital cars.

It seems to me that the objects in view should be, to furnish such simple aseptic dressings and apparatus as will prevent any further soiling or infection of the wound, to prevent or control hemorrhage, to immobilize injured parts, and to transport the injured person to a place where he may have careful, skilled, and permanent treatment just as soon as possible. I believe hospital cars cannot do all this. In this age of many excellent hospitals along railroad lines, the publicity and some added discomfort in the old manner of transporting injured persons are far less harmful than delays in delivering them at the hospitals where they may find rest and permanent treatment at the hands of experienced men.

Is there, then, no field, no call for hospital cars on railroads? I believe decidedly there is. First, on a railroad which is composed of a number of short lines radiating from a common center, when the "center" has hospital facilities and the short lines have none, the car may be efficient for conveying relief in apparatus, a skilled surgeon, and means of transportation. Second, suburban short lines might also use a hospital car efficiently. In both these instances one or two cars would suffice, and these roads could afford to employ a skilled surgeon to accompany the car. In both instances the object would be first aid and the bringing of the patient to the hospital base, namely, the city in which the terminus might be.

Third, hospital cars would be very efficient on railroads which have a system of small emergency hospitals along the lines and one or two "base hospitals" at the termini. They would be used in transporting patients from the emergency hospital to the base or principal hospital.

Fourth, it may be considered ahead of the times, but I believe an especial need for hospital cars is for (intermittent) use on through

express trains to transport sick and injured passengers, for which service people of means would gladly pay.

Most physicians can recall many instances of illness, clearly contagious or infectious, on crowded trains in such conditions that they would communicate the diseases. It is a matter of commonest experience for persons suffering from pulmonary tuberculosis to travel long distances in railway coaches. Sleeping cars are especially apt to be selected for these ailing persons. Efficient disinfection of railway coaches, especially sleeping coaches, is usually neglected. Various States have passed stringent laws requiring the careful embalming, disinfection, and hermetic inclosure of corpses of persons dying of contagious diseases during transportation on the railroads. But individuals while still alive, when suffering from any one of the contagious or infectious diseases, may travel without any let or hindrance on any railroad of the United States, unless their disease is *accidentally* discovered, and, as a rule, are placed in the very cars which are most frequented and most difficult to disinfect.

Understanding, as we do, the usual methods of transmission and the specific cause of pulmonary tuberculosis, it is amazing that no restriction has yet been placed upon the transportation of persons who are in advanced stages of this disease. It would be a barbarous prohibition to prevent tuberculous persons from using railroad cars in order to go whither their one chance of recovery may be. The only proper, safe, comfortable, and sanitary solution of this problem of contagious and infectious disease-spreading custom is for railroads to furnish properly equipped hospital cars for any doubtful case of disease to its destination, and so separate it entirely from the other travelers on the train. In order to make this system efficient, the coöperation of physicians generally must be obtained, and the various States should pass laws requiring the use of isolating or hospital cars for sick persons. The patient and his attendants would have seclusion, more comfort, and efficient treatment might continue, without any danger to others.

These cars should be constructed so as to be inconspicuous on the outside, and have the simplest fittings commensurate with comfort and efficiency, and everything should be so arranged and constructed that proper sanitation during, and thorough disinfection after, the use of the car might be obtained.

Only two or three cars of this kind would be necessary on a line of a thousand miles of main track. If they were properly stationed, they might also prove very efficient in cases of serious catastrophes along the line.

RAILROAD HOSPITALS.

In populous regions and when a railroad line traverses a number of large towns which have hospitals, special railroad hospitals are not necessary. It is more economic and efficient to arrange with the hospitals along the route to receive the casualty cases from the road. This arrangement, however, disorganizes the proper system and order

of surgeons and reports on the road, and it takes away from the chief surgeon the control, and in many instances, proper information concerning the progress and termination of the cases, unless, as should be done, the chief surgeons of the hospitals are made *ipso facto* surgeons of the railroad company. This arrangement with hospitals in towns along the route would make it comparatively easy to select the local surgeons, since they would be recruited from the staff of the hospitals.

In sparsely settled regions, especially in a newly opened country, hospitals founded and maintained by the railroad are necessities. Small emergency hospitals, and two or more large base hospitals, should be distributed along the line. These hospitals should be, of course, under the general direction and control of the chief surgeon. A division surgeon should be immediate chief of the base hospital, which, other things being equal, on a long line or system, should be located one at either terminus, and one as nearly as may be midway between. The emergency hospitals would best be established near large transshiping yards and junctions, and these should be controlled by the local surgeon or surgeons in whose territory they happen to be. When the territory of more than one surgeon is concerned, regular rotation of the medical officer-in-charge should be the rule, at stated intervals. The emergency hospitals would do the work indicated by their name, and as soon as the patient could be safely moved, he should be taken to one of the base hospitals, where, as a rule, all major surgical operations should be performed.

For a large railroad system I am convinced a third variety of hospital would add markedly to the efficiency of the treatment, relieve congestion in the base or terminal hospital, and enable the surgical department to keep track and proper records of the cases and hold them in charge until they are quite well, viz., a well-managed and well-located convalescent hospital or home. Patients who had progressed so far that no further active treatment was necessary, as, for instance, fracture cases, spinal injuries, etc., are frequently very slow in recuperating at their homes; they become more or less a burden to their families if they are very poor, they become anxious, worried, and discouraged, and in this frame of mind fall easy victims to the wiles of speculative lawyers, who induce them to undertake unjust damage suits. The anxiety and worry, and especially damage suits, prolong the disability of the patients far beyond the reasonable time required for restoring cases of this kind to their work and wage earning.

Besides, certain measures might be employed in these convalescent homes for restoring suspended functions to limbs, for which there would be no time in a general hospital. Massage, passive movements, and electricity might be skilfully employed, and the use of simple gymnastic apparatus prescribed and practised. This course of treatment, together with good air, good simple food, good water, and pleasant surroundings would undoubtedly cut short the period of disability and restore many good men to their work much earlier than ordinarily. Men who had

lost a limb might wait in the convalescent home until an artificial limb might be properly adjusted, and at the same time gain strength by doing light work in the grounds and gardens attached to the home.

MEETINGS OF RAILROAD SURGEONS.

The surgeons of a railroad line or system should meet socially at stated intervals, have opportunities to discuss the surgical work on their own road, and compare their work with that on other lines. There should be at least one general annual meeting, while the surgeons of each division should meet at least every six months. Every three years a meeting of railroad surgeons of a whole section of the country should be established, and every five years a regular formed National Congress of Railroad Surgeons should be held.

PREVENTIVE METHODS AND FIRST AID IN INDUSTRIAL ESTABLISHMENTS.

Much may be done in preventing accidents also in factories, mills, and the working trades generally. The United States is lamentably behind the Continent of Europe in adopting and establishing measures to induce the employés to safeguard themselves from injury while at work. Many individual manufacturers have introduced safety appliances from time to time in their factories, but usually they have been discontinued because, as they say, "my men won't use them." It seems curious, and yet it is true, that men in dangerous employments are so careless of their safety that it requires a regular system of education to make them appreciate the value and to employ devices invented to prevent and lessen injuries. This fact is so thoroughly appreciated that now in several parts of Germany, in France, in Austria, and in Holland there have been established what are called "Museums of Security." As William H. Tolman, director of the American Institute of Social Service, says: "The Museum of Security aims to become a permanent exposition, not only of devices for the prevention of accidents of laborers, but of the best suggestions originated by any person or institution to help workmen in any way."[8]

These Museums of Security have induced inventors to devise, manufacturers to adopt, and laborers to use, many devices to prevent accidents in all the trades, mills, quarries, and mines. In the United States "five of the States have enacted laws providing against accidents in the building and construction trades—nine States require factory operators to report accidents suffered by their employés."[9] Unfortunately, very incomplete data are furnished, and in such shape that it is impossible to compile accurate statistics from them. The report from the New York State Bureau of Labor for three months, which I have quoted,[10] seems the nearest approach to accuracy and completeness. It is for so short a time, however, that one hesitates to base a calculation upon it. These figures and my own experience in the midst of a large manufacturing community indicate unquestionably that accidents are

numerous, and, furthermore, that many of these could be prevented if our States would adopt the system of "Museum of Security" similar to those in Berlin, Munich, Vienna, Paris, and Amsterdam, to educate the workmen and to compel the employers to adopt every adequate mechanism for the prevention of accidents.

FIRST AID IN FACTORIES AND MILLS AND MINES.

As I stated before, mines usually have surgical staffs, and either their own hospitals or a working arrangement with some hospital in the neighborhood for the quick reception and skilful treatment of their employés. As was also stated before, mine accidents are apt to produce frightful and multiple injuries, and while, to a great extent, they escape the infection of injuries to workmen above ground, the severity of the traumatism produces great shock. Early and careful transportation is necessary; the measures for the prevention of hemorrhage should be promptly employed. As a rule, this first-aid work should be done in the mine itself. Miners should, therefore, also be instructed in the elements of first aid to the injured. It is a pleasure to say, to the credit of the largest of Pennsylvania anthracite producers,—the Reading Coal and Iron Co.,—that systematic and careful instruction has been given their men for over a year by Dr. George Halberstadt, of Pottsville, and the result has been most gratifying in the handling of injured miners and the saving of much suffering and of many lives. The fact that factories of various kinds are usually located so near towns and cities that outside surgical aid may be quickly obtained has made mill managers slow to adopt any adequate system for rendering first aid. The usual system of departments in mills makes it comparatively easy to establish a regular first-aid system within their own walls. That such a system leads to great good I know. Some years ago I suggested to an officer of a large steel mill, which employs over 6500 men, that it took so long for our hospital ambulance to get to the works in case of an injury that the mill ought to have its own ambulance and be properly fitted up with some aseptic emergency dressings. This was promptly done. It soon appeared, however, that when injuries occurred in departments some distance away from the ambulance, the man sometimes almost bled to death, or the wounds were further soiled by attempts of ignorant workmen to cover them with wearing apparel of various kinds before the ambulance arrived. It was then suggested that regular dressing stations should be established in every department of the mill, and that each of these stations be supplied with an adequate kit of clean dressings. This also was done. Finally, I volunteered to give regular instruction to heads of departments and to selected men in first-aid work; this was promptly accepted. Now this mill has a regular central station or emergency room, and in every department a small room is set apart for first aid, and in every department there is an intelligent man who has seen and himself practised the first aid to various kinds of injuries. The good result, both in the saving of limbs

and of life and in the morale of the men, has been very gratifying indeed. The cost of establishing these dressing stations and keeping them properly stocked is so slight that mills all over the country ought to be willing to establish them.

PECULIARITIES OF ACCIDENT CASES.

Railroad Accidents.—Injuries on the railroad are peculiar only in their great severity and the multiple character of the injuries. On

FIG. 426.—THE EFFECT OF CAR-WHEELS PASSING OVER EXTREMITIES.
Complete comminution of both upper extremities in their upper third.

FIG. 427.—INJURY TO THE SKIN PRODUCED BY PRESSURE OF A CAR-WHEEL WITHOUT ACTUALLY PASSING OVER THE EXTREMITIES.
The wheel pushed the extremity along and pressed it, but did not pass over it.

this account, and because of the horror so commonly preceding and attending these injuries, there is, as a rule, more shock from railroad

injuries than from any other class of accidents. Psychic shock is especially severe. Subcutaneous lacerations of the soft tissue of a very severe character are common; and though it seems a little paradoxic, it is true, nevertheless, that severe injury, commonly entire destruction of the skin of a section of a limb, with very slight subcutaneous injury, frequently results from railroad accidents. Squeezing between bumpers or between the ends of the cars produces the first, and impact of a wheel as it pushes a member along a rail without actually passing over it causes the latter form of injury.

FIG. 428.—ACCIDENT FROM BEING CAUGHT BETWEEN CAR BUMPERS.
Crush of forearm involving chiefly the muscles and bones.

FIG. 429.—ACCIDENT FROM A CAR-WHEEL.
The same injury as shown in Fig. 430. The plantar surface of the foot is split in several jagged lacerations and the soft tissues are lacerated.

Motor-car injuries are very similar to railroad injuries. The one added especial danger is the soiling of the wounds by the dust of the highway. This is much more apt to produce suppuration in the wounds, as it is exceedingly difficult to clean them thoroughly of the fine foreign matter, and as the highways over which horses travel are infested by

the tetanus bacillus, these patients run a grave risk of tetanus. The greatest care should be exercised in dressing these wounds to get them clean, and thoroughly to wash out the deep recesses of the wounds. When practicable, one should not close them by sutures for several days, in order to expose the wounds to the air

FIG. 430.—ACCIDENT FROM A CAR-WHEEL. Dorsum of the foot shows the mark of the flange; complete destruction of the skin, though there is no break in the skin.

FIG. 431.—RAILROAD ACCIDENT. Crush of the heel and laceration of the lower third of the leg, caused by car-wheel.

and sunlight frequently. The tetanus bacillus is an anaërobic variety, and will not develop unless covered up, and air and light are excluded.

FIG. 432.—COMMINUTION OF THE METATARSUS FROM AN ACCIDENT CAUSED BY A HEAVY MASS OF STEEL FALLING ON THE DORSUM OF THE FOOT.

Steamboat Accidents.—Steamboat accidents have no especial peculiarities except the psychic shock which commonly belongs to a very marked degree to catastrophies on the sea. The modern steamship is a huge machine shop, having almost all the known mechanical

and electric contrivances. The accidents which occur, barring catastrophies to the hull, are of the kind which occur in any large factory or machine shop.

Mill and Factory Accidents.—Mills and factories of various kinds produce a large variety of injuries. They will be considered

FIG. 433.—ACCIDENT FROM REVOLVING MACHINERY.
Crush of the forearm; skin torn in a large irregular wound and dissected from the muscles; muscles extremely lacerated; drainage by canalization.

under the general classification of wounds. Nothing of any vital importance distinguishes them as a class.

Mine and Quarry Accidents.—Multiple or complicated fractures, and explosion wounds are the especial classes of injury which belong to mine and quarry accidents. Fractures of the vertebræ are especially

FIG. 434.—MULTIPLE BURNS OF VARYING DEGREES PRODUCED BY THE SPLASHING OF MOLTEN METAL.

common among miners. The explosion wounds are lacerations, frequently very extensive and severe, with, at the same time, severe burns of the lacerated area. Very marked shock is always an early feature of the injury; the lacerations are usually very numerous, and of all degrees of severity. Usually the skin is charred, sometimes almost to a crisp, and innumerable particles of foreign matters, small pebbles,

bits of coal and stone are driven through the skin into the subcutaneous tissues. There is one saving grace about wounds in mines, however—they are rarely infected, unless through the carelessness of the attending surgeon. The carbon from the coal mines and the pebbles from other deep mines carry no septic flora into the wounds, and though they look dreadful enough, what seem to be desperate cases frequently get well if they are tided over the early hours of injury.

TREATMENT OF ACCIDENT CASES.

First Aid.—It has been frequently stated in the foregoing pages that the treatment of an injury should begin immediately after the accident—by amateur first aid if no surgeon is at hand. Simple dressings should be kept on every railroad train, on every steamer, in every factory and mine for this purpose. This first aid should consist in preventing hemorrhage, if necessary, and so to protect an open wound that no further soiling will occur, and to immobilize a fractured limb so that further injury from the broken bones and excessive pain on account of movements shall not occur. Then the injured person should be sent

FIG. 435.—ILLUSTRATING THE RESULT OF AN ACCIDENT FROM A FALL FROM A HEIGHT. Compound dislocation of the astragalus. Complete extrusion of the astragalus and ends of the leg-bones. Severe contusion of the other foot.

at once, if practicable, where he may receive adequate surgical attention and permanent treatment and dressings.

After nearly every serious injury which has occurred during the waking period, that is, when the victim is not asleep, there is more or less shock. During this period of vasomotor tetany affecting the peripheral vessels there is very little hemorrhage, even if large vessels be severed. When reaction takes place, however, the hemorrhage will surely begin. It is extremely important, therefore, that measures to control hemorrhage shall be employed very soon after the injury, in order to anticipate and to prevent hemorrhage. If a surgeon sees the injured person during this stage and can see the ends of large vessels severed in an open wound, he should ligate the vessels at once if he has aseptic ligatures with him, and if he can do it without loss of

time. A person, either medical or lay, who is not accustomed to handling fresh wounds, had much better employ elastic constriction for the purpose of temporarily controlling hemorrhage. If no rubber tourniquet is at hand, two pairs of elastic suspenders may be used for this purpose when a limb is injured. If no elastic bands of any kind can be obtained, a large clean handkerchief may be tied about an extremity and then twisted by a stick thrust under the handkerchief, and turned until all bleeding ceases (Spanish windlass); then its constriction should be maintained by tying the stick in place.

These tourniquets, whether elastic or not, are very painful, and they are very apt to kill the tissues beneath them if they are left on for any length of time; for this reason they should be applied as near as possible to the wound, and always, when possible, over injured tissues. A large wound which makes a tourniquet necessary always involves the tissues several centimeters above the severed vessels; a tourniquet may be applied 6 cm. above the apparent limit of a large wound and not occasion any added loss of limb if a subsequent amputation becomes necessary. But it must be remembered that a tourniquet applied too close to a wound which has severed nearly all the soft tissues of an extremity, especially a tapering extremity, will slip downward, and the blood-vessels, released from pressure, will bleed even worse than if no tourniquet had been applied. If the patient will surely receive permanent surgical treatment and dressing within three hours, the tourniquet may be applied anywhere above the wound; within this time no lasting harm will result.

FIG. 436.—VIEW OF THE BACK OF A YOUNG GIRL AFTER VERY SEVERE BURN CAUSED BY A FLAME.

If the bleeding wound is on the trunk or head, pack the wound closely with clean gauze or perfectly clean handkerchiefs, and then hold them firmly in place with a bandage; this will usually suffice. In trying to control hemorrhage from the scalp by pressure it must be remembered that so long as large clots remain under the scalp between it and the bone it will be impossible to control the hemorrhage. These clots may usually be pressed out by firmly pressing the scalp down upon the bone, beginning about 4 cm. from the edges of the wound and gradually approaching the wound from either side. When this is done, a large compress of gauze should be laid immediately over the wound and firm pressure made upon it by a bandage which will also hold it in

place. For temporarily immobilizing limbs after fractures pieces of clean boards, or bundles of twigs or straw, may be used for splints.[11] Or, if nothing else is at hand, canes or umbrellas of bystanders may sometimes be employed. In the absence of any such mechanical means, in a case of fracture of the upper extremity, it may be fixed to the side of the body by a bandage improvised from anything which will go around the chest and abdomen—handkerchiefs, strips of petticoats, shirts, or what not. Another way is to split the sleeve longitudinally, then pin this over the extremity to the side of the coat. This coat must be buttoned up closely over the chest (Fig. 438). In the similar absence of any possible thing to use as a splint for a fractured lower extremity it may be fastened to its fellow by bandages or handkerchiefs, or by pinning the trouser leg or drawers of the injured

FIG. 437.—SIDE VIEW OF A YOUNG GIRL AFTER VERY SEVERE BURN CAUSED BY A FLAME.

FIG. 438.—FIXATION OF THE UPPER EXTREMITY TO THE SIDE OF THE CHEST BY MEANS OF A SPLIT COAT-SLEEVE.

member to that of the uninjured side. In rendering first aid for a fracture of bones of either the upper or lower extremity, unless there is hemorrhage, the sleeves, and in a man the trouser legs, should not be cut or removed, for these act as padding for the splints. Unnecessary removal of clothing is apt to result also in chilling the patient. This is true in any case, but when it is absolutely necessary the clothing must be removed. *Whenever there is hemorrhage the clothing must always be sufficiently cut to inspect the wound and to judge of its character.*

In the case of an injured woman, her corsets should always be loosened in order to give her more freedom of respiration, but if her ribs have been fractured, it will be best to fasten the corsets again before she is transported.

A matter of great importance is the covering of injured people during transportation. Great harm may be done by using very much soiled coverlets or blankets; *especially is it important never to use horse blankets to cover human beings who have open wounds.* This applies especially to wounds of large areas—for instance, burns. I have had several cases of tetanus develop after burned cases had been brought to the hospital covered by horse blankets. The patients should be kept warm by sufficient covering, but the layer immediately over their skin should be clean.

I cannot emphasize too strongly the vital importance of never attempting exploration of wounds and reduction of fractures at the scene of accident amid doubtful surroundings, with probably soiled skin (both the patient's skin and the surgeon's hands) and no adequate facilities for cleaning the wound or for splinting or immobilizing the limb. It should be taken as an axiom that all accidental wounds are infected. In this day of clean surgical methods it is criminal to investigate the extent and character of a wound by thrusting the finger into the wound at the scene of the accident. I have seen more deplorable consequences follow the well-meant but thoughtless explorations of eager young surgeons, than from almost any other untoward feature of an ordinary injury. Medical schools should teach incipient surgeons that attempts at careful differentiations by the wayside are indications of ignorance, and that this stupidity leads to death. Except in a general way, and only for the purpose of meeting the immediate indications, no attempt to find out its whole extent and exact nature of the injury should be made until the patient has been carried to a clean place, or after careful washing and disinfection of the wound and its immediate surrounding or connecting skin; and especially not until the surgeon shall have carefully washed and disinfected his own hands. If practicable, seriously injured people should always be treated in a properly equipped hospital.

Transportation.—Unless the accident has occurred where it is possible to obtain a regular ambulance service and a good stretcher, some provision must be made for carrying the patient. Frequently it is recommended to employ a door or a shutter for this purpose. This is a barbarous thing to do, because it is exceedingly difficult for the bearers to retain their grasp on the shutter or door as it is ordinarily carried; they must stop and exchange hands frequently and they must also rest now and then. Every time one of the bearers changes the position of his hand, the rigid door or shutter is tilted; this causes a rolling of the patient about on the rigid surfaces and greatly increases his suffering. Besides, it is very hard to walk any distance alongside of a door or a shutter carrying a heavy man. The proper way to carry a door or shutter with an injured person on it is for four men about equally tall to carry the corners of it on their shoulders. This is apt to frighten the injured person considerably on account of the height; with a very nervous person, this position would be quite impossible. It is so easy to improvise a stretcher by thrusting two poles

through the sleeves of two coats, and then wrapping the tails of the coats around the poles above and below, and securing them by pins, wire nails, or other means. The poles may be of any kind, not too heavy and not too short, and their elastic strength and resistance must be carefully tested before they are used. The essential point in making this arrangement is to see that the shoulders of the two coats meet one another in the center of the improvised stretcher; in this way the

FIG. 439.—IMPROVISED STRETCHER.
Two men's coats are used, the sleeves turned wrong side out; two poles are thrust through the sleeves, and the skirts of coats are turned over the poles and pinned in position. Thongs of leather, cord, etc., or small wire nails may be used to fasten the coat-tails instead of the pin.

buttocks of the patient and the greatest weight will fall where the strongest part of the stretcher is, viz., in the middle (Fig. 440). It must always be remembered that stretcher-bearers should *never* walk in step, but should glide or shuffle along. On the other hand, when two men are carrying an injured person in their arms by grasping him under his shoulders and by his thighs, they must *always* walk in step.

FIG. 440.—THE IMPROVISED COAT STRETCHER IN USE.
Note that the shoulders of the coats come together in the middle of the stretcher, where the buttocks of the patient rest, the strongest part thus bearing the greatest weight.

Permanent Treatment and Dressings.—The first thing the surgeon who makes the first careful investigation should do in all accident cases is to ascertain if all bleeding has been controlled. I have known neglect to do this to cost several lives. If hemorrhage continues, this must be controlled before anything else is done.

When hemorrhage is absolutely controlled, the next thing is to ascertain the physical condition of the injured person. Inexperienced surgeons are frequently so eager to begin attending to the *wounds* that they

entirely forget the *wounded person.* They go through the very long and proper aseptic technic necessary for the local injury, and are astonished, when the dressing is completed, to find the patient dead.

After very serious injury, and, indeed, I believe *before* many injuries, the victim is in a condition of shock (Vol. I., p. 922). The condition called shock may be brought about by three causes—namely, first, emotion, *i. e.*, that produced by mental effect, I call this psychic shock; second, injury to the nervous centers; third, hemorrhage.

Psychic shock usually precedes the injury. It is the condition brought about by the terror a conscious person has of a seemingly inevitable and dreadful catastrophe. It is a condition of total anesthesia. A person falling from a great height; a brakeman with his feet caught in the frog of a switch and moving cars coming down upon him; the workman whose clothes are caught on the shaft of revolving machinery and who, as he believes, is being dragged inevitably to his doom—all these fall into a condition of nervous tension which brings about the condition of psychic shock and which deprives the individual absolutely of all feeling; and when the awful and dreadful moment *does* come, the injury is absolutely not felt at all. I have time and again questioned men who have been frightfully injured under conditions such as I have indicated, and always they have said they did not feel the crush at all. Even if no injury actually occurs, when the mind has been so wrought upon, the condition of shock is just as profound. This shock lasts a variable period, according to the individual. It is retroactive. I have many times known it to occur with impressionable individuals some time after an injury by recalling the scenes and horrors of the accidents. This, I think, explains many cases of so-called "delayed shock." This variety of shock is lessened by an anesthetic, for the pulse and the arterial tension generally improve under the anesthetic when an operation is undertaken. The other forms of shock are discussed in Chapter XVIII.

In treating shock, one must find out, if possible, what has produced the shock. The absence of any serious wound to the head or spinal column, and the fact that no great hemorrhage had taken place, would suggest psychic shock. For this form measures to restore heat to the surface, and the relaxing and soothing effect of a full dose of morphin with atropin given hypodermatically, will diminish the immediate urgency of the symptoms. In case an operation is necessary, ether, as a rule, may be given safely, and, as I said before, the pulse will improve and the color become better under the anesthetic. Afterward the greatest care must be observed to keep all suggestions of the circumstances of the accident away from the patient.

The second variety of shock requires careful and prolonged treatment. This is given in Vol. I., p. 938.

The third variety, viz., from hemorrhage, is the one which is the most difficult to manage. This acute anemia is a most dangerous condition. Except the necessary manipulations and measures for absolutely controlling hemorrhage and introducing saline solution or blood,

no sort of operation should be attempted during this condition. (See Vol. I., p 938.) Crile has recently suggested direct blood infusion by anastomosing an artery of the donor with a vein of the patient.

After hemorrhage has been controlled, and if the general condition of the patient will permit, the clothing should be removed. This should be done with very little disturbance of the patient in every case, the clothing being *removed* from the *sound* arm or leg *first*, and if *replaced*, put on the *injured* limb *first*. But in bad cases the clothing should be *cut off and not be drawn over the extremity*, as this requires too much movement and effort for the patient. In every case the clothing should be cut from any badly injured limb.

It is presumed that the surgeon has a room provided with plenty of hot sterile water and with at least one of the ordinary antiseptics—either phenol, mercuric chlorid, or formaldehyd solution. A douche or irrigating apparatus is also necessary, and a sufficient supply of sterile absorbent gauze and cotton, besides roller bandages. Splints may be improvised. A table will be a great convenience, although not absolutely necessary. A piece of rubber cloth one yard square to put under the injured part and catch the water used in washing and douching is also a great convenience. By turning up the edges of this rubber cloth and keeping them elevated by some cloths rolled into a large rope and laid underneath, a receptacle and gutter may be made which will catch and drain the fluids off into a catch basin or pail, and thus save inundating the table and floor of the dressing-room.

After everything necessary for the dressing is ready at hand, the outer clothing all removed, and the patient covered by clean warm blankets as thoroughly as the situation and nature of his wounds will permit, the surgeon should remove the temporary first-aid dressings, cover the wound with fresh sterile gauze or towels, and then carefully wash the surrounding skin with some soft soap or fluid soap—*never with a cake* of soap. If soap in a cake is the only kind to be had, it will be best to shave this off with a knife and liquefy it in one-fourth alcohol and three-fourths water, then use this fluid soap by pouring it on a packet of gauze. If very much soiled with oily soot, turpentine may be used to remove it. Shave the part carefully and thoroughly, scrub the skin by rubbing in the soap, then with a ball or wad of gauze and sterile water thoroughly scrub off the soap and dirt; be careful always to rub in a direction *away* from the wound during the scrubbing process, so that the suds and dirt shall not be brought into the wound. Three or more applications of soap and scrubbing will be necessary. Wash off with sterile water, then wash with ether. Next wash thoroughly with 1: 60 phenol solution or 1: 1000 formalin or bichlorid of mercury solution. If the operatingsurgeon has conducted the foregoing cleansing, he must now stop and carefully wash and disinfect his own hands; if an assistant has done the washing of the patient, the surgeon should now be prepared with sterile hands to go on with the further manipulations. The covering of the wound should now be removed, and the wound be thoroughly irrigated, first with simple hot saline solution to remove all loose matter,

and then very careful douching should be done with a warm 1: 1000 mercuric bichlorid solution or 1: 5000 formaldehyd solution. This last is very painful in many cases, as the formaldehyd is very irritating unless the patient is anesthetized. These disinfectant solutions should go into every part and crevice of the wound; they may afterward be washed out with a hot sterile saline solution. Now the surgeon, with hands resterilized, or with sterile rubber gloves on his hands, should carefully investigate the extent and severity of the wound, and decide what is necessary to be done.

In case a limb is crushed completely off, it is not necessary to attempt any cleansing of the begrimed and lacerated tissues at the end of the stump. This stump-end should be carefully covered with thick layers of aseptic gauze, held in place by stitches through the skin or by a tight bandage, and the tourniquet should be kept on until the tissues are removed by amputation. No septic absorption will take place if this is done. In case amputation of a crushed limb is necessary, the cleansing and disinfecting processes just mentioned should be used over the skin of the extremity above the crush, and, lastly, it should be further disinfected by a saturated solution of potassium permanganate, and this be washed off with a solution of oxalic acid. Then the amputation should be done immediately, the patient having been anesthetized before the cleansing was begun.

The question with major accident cases is not, as a rule, whether one shall operate or not, for some operation must always be done after most major accidents: it is rather how much of an operation should be done and is any radical operation called for. While it is true that every ordinary major wound resulting from accidents is, *ipso facto*, a soiled and infected wound, and while it is in a great many cases impracticable thoroughly to disinfect the wounds unless an ablation of the part is done, nevertheless some very dreadful wounds do extremely well, and apparently hopeless injuries, as regards the life and usefulness of a limb, get well with fairly good function. I would, therefore, lay down the rule that in case hemorrhage may be controlled without the prolonged use of a tourniquet, and good disinfection may be obtained, in case of doubt, do only conservative operations after a fresh injury and wait for developments.

As regards the question of amputation in injuries of the extremities, in a general way, whenever more than 6 cm. of the shaft of the bone of a limb is crushed, in view of the injury to the soft tissues, which the crushing force always produces in compound comminuted fractures, amputation is necessary. If the principal vessels high up in the arm or thigh are torn in cases of severe lacerated and contused wounds of the arms and thigh, an amputation will be required. In this connection one should always bear in mind the possibility of suturing or of anastomosing the torn vessels, as suggested by Carrel.[12 13] If the tissues on the outer half of the arm, or posterior and external half of the thigh, were not badly injured, I should ligate the vessels and wait.

In cases of very severe lacerated and contused wounds of the extrem-

ities, when the vessels and nerves, together with the muscles of half the limb are crushed, amputation will be necessary. When the skin of two-thirds of the periphery of a limb, though not broken, has been crushed and there is severe comminution of the muscles immediately beneath, an amputation is inevitable. Circular or annular comminutions and lacerations of the tissues nearly always require amputations. Severe comminution of the muscles is not an indication for amputation. Severe lacerated wounds running longitudinally or obliquely along the axis of a limb, though they involve all the soft tissues on that side, and though they extend through the whole forearm and arm, or the leg and thigh, are not indications for amputations.

Conservative operations should be done immediately in every case of doubt, or in which they are unmistakably indicated, unless, as I have said before, the patient's condition is such that no operation can be done. These operations are themselves frequently of major importance. Injuries to the head, for instance, may require removal of fragments of bone and blood-clots from the cerebral tissues, clearing out detritus, making provision for drainage, and doing some heteroplastic operation for closing the dura mater and the walls of the cranium.

Injuries to the thorax may require exsection of jagged ribs which are puncturing the lungs, evacuation of fluid and clotted blood from the pleural cavity, and suturing the pulmonary to the parietal pleura to prevent collapse of the lung.

Injuries to the abdomen not infrequently require celiotomy and suturing of lacerated viscera, occasionally of exsections of a viscus, cleansing of the peritoneal cavity, and drainage.

Injuries to the limbs frequently require *immediate* suturing of torn tendons and nerves, suturing or ligation of blood-vessels, fixation of bones by wire or plate or nails, and suturing of muscles and large areas of skin.

The cardinal principles in all this work are, first, cleanliness as nearly perfect as possible; second, bloodless methods of operating; third, good drainage.

TREATMENT OF VERY SEVERE AND MULTIPLE INJURIES.

The general treatment of wounds is discussed in Vol. I., p. 882. Though the conditions which belong to this chapter are those of multiple injuries, and usually of a complicated kind, the same general principles apply. Multiple injuries lower the general resistance and reduce the opsonic index of the individual so much, however, that these wounds are much more liable to suppurate. It is necessary always to exercise extreme care in cleansing and disinfecting the wounds and their surroundings, to save every possible drop of blood, and always to procure the best possible drainage. Large mass aseptic dressings should be put on, and, when practicable, rest of the part should be secured by splints or careful bandaging.

One class of injuries should, however, have at least separate mention—those produced by *explosions*. These injuries are lacerations of all

degrees of severity, and at the same time burns of the lacerated areas. The lacerations may be very extensive and multiple. Thus, I have seen avulsion of a hand and very extensive laceration of a shoulder and dreadful multiple lacerations of the face, as well as scorching of all these areas, in the same individual. The large lacerations and avulsions need no special mention. Cases of innumerable punctate lacerations, if one may so describe them, with severe burning, result from blasting powders. The exposed parts, the face, neck, hands, and forearms, are usually especially involved. The lacerated punctures are produced by small bits of pebbles or bits of coal, which are driven through the skin by the explosion and lodged in the subcutaneous tissues. These bits vary in size from a millet-seed up to pieces the size of a hazel-nut, *i. e.*, about 1 cm. in diameter The eyes are frequently involved and destroyed (Fig. 441). These cases are usually tremendously shocked. Unless the explosion has occurred on the surface of the

FIG. 441.—EXPLOSION ACCIDENT.
Whole face and neck riddled by punctate lacerations. Several hundred bits of stone are buried in the subcutaneous tissues. Destruction of both eyes.

ground, the bits of mineral matter driven into the subcutaneous tissues may produce no suppuration, but they will produce very marked discoloration if allowed to remain. They should always be removed from the face and eyes. On account of the weak condition of the patient, this cannot all be done at the first permanent dressing, as the process is a very tedious one and often very painful; nor can efficient bathing be employed. The charring of the skin, however, sterilizes it quite effectually, unless some soiled application has been made to the injured area. It is best at the first dressing only carefully to investigate and remove the pebbles, powder, etc., from the eyes, and bathe them carefully with a saturated boric acid solution, and then hurriedly go over the other areas with a 1 per cent. solution of dioxid of hydrogen and apply a dry aseptic dressing. After a few days, when the superficial layers of the skin which have been burned begin to come away, the punctures may each be investigated and the stones, etc., removed with forceps.

GENERAL EFFECTS OF MULTIPLE INJURIES.

On the Vascular System.—First, serious wounds always lower the blood-pressure.[14] Second, multiple injuries also markedly lessen the quantity of oxygen in the blood.[15] This may be due, in part, to the slow, shallow respiration, but undoubtedly it is also due, in part, to the loss of red blood-corpuscles and to the inhibited cellular action which occurs immediately after a serious injury. Unless the patient is almost exsanguinated, the blood is much darker than it should be.

This, by the way, is a strong reason for *not using chloroform* as an anesthetic after multiple or very serious injuries.

On the Respiratory System.—The respiratory function is usually much depressed. Respiration is slow, shallow, and incomplete. Yawning may occur frequently in order to supplement the incompetent inspiration.

On the Nervous System.—Decided dulling of both tactile and sensory functions is usual, and all afferent impulses are slow and frequently irregular. Coördination is good, but slow. The nerves of special sense, especially those of hearing, smell, and taste, besides the tactile nerves, are frequently so obtunded that they seem for the time paralyzed.

On the Muscular System.—General and complete relaxation of the muscles is the rule. The sphincters are so relaxed that involuntary passages of feces and urine frequently occur.

On the Secreting Organs.—The digestive organs are weak, the saliva and the gastric and intestinal juices are diminished, and the actions of the liver and pancreas are very much diminished. Constipation usually occurs, stools are hard and light colored, and I have frequently noted temporary glycosuria.

On the Excreting Organs.—Skin.—At first the action of the skin is also markedly diminished. After reaction takes place the sweat-glands are sometimes unusually active. Very marked sweating occurs in many cases after some multiple injuries for two or three days.

On the Kidneys.—In order to determine the effects of severe and multiple injuries on the kidneys I had a series of careful examinations made, and found that the quantity of urine for the first week after the injury is nearly always diminished—in very bad cases markedly so. Reaction is oftenest alkaline. Uric acid is usually increased. Urea is markedly diminished. The degree of variation of the chlorids is not especially important. The total solids are lessened, especially in bad cases. Burns frequently develop temporary nephritis. Bad fractures sometimes have leukocytes and degenerated red blood-corpuscles as well as excess of urates in the urine. Albumin very rarely appears, except when nephritis develops after burns. As a rule, the microscopic findings are not important, except after fractures of large bones or of several bones, as noted above.

THE RELATIVE FREQUENCY OF THE VARIOUS KINDS OF INJURIES.

There are no reliable statistics published to show the relative number of injuries of various kinds which result from accidents. In order to determine this point I have analyzed 4065 accident cases which have been treated in my service at St. Luke's Hospital, South Bethlehem, Pa. In this service have been accidents from railroads, factories of various kinds, coal-mines, and various kinds of quarries, besides all sorts of accidents of home life.

There were:

Burns		285
Contusions		510
Lacerations		640
Comminutions		499
Avulsions		232
Fractures	Simple 714	1585
	Compound or Complicated 871	
Dislocations		85
Sprains		78
Gunshot wounds		99
Incised wounds		52
Total		4065

One notes in going over these figures that fractures were more than twice as frequent as any other one variety of injury; the compound and complicated fractures outnumbered the simple fractures.

Next to fractures, lacerated wounds were most frequent; then came contused wounds and comminutions; burns and avulsions are very close together; dislocations, sprains, gunshot, and incised wounds were comparatively few; 3245 of the cases were treated conservatively; 53 of these cases were admitted in hopeless (moribund) conditions. Leaving these out of account, there were 127 deaths, or 4.08 per cent. mortality of cases treated conservatively. The average number of days for each patient in the hospital of the cases treated conservatively was 23.03.

Eight hundred and twenty of the cases required amputations.

There were 726 single amputations, with a mortality of 4.95 per cent.
There were 84 double amputations, with a mortality of 14.28 per cent.
There were 10 triple amputations, with a mortality of 30.00 per cent.

The average number of days in the hospital of amputation cases was 22.6.

The above figures show that conservative measures—that is, efforts to save an injured member without amputation—resulted in a lower mortality than did amputations. Amputations were followed by a mortality of 20.4 per cent. of all the injuries requiring amputation, while the mortality of the cases treated conservatively was only 4.08 per cent. Even simple amputations show a higher rate of mortality (4.95 per cent.) than that following conservative treatment (4.08 per cent.). Amputation is resorted to in my service only in cases which seem to present absolutely no hope of saving the limb. These cases may be

regarded as of a severer type of injury, and, as a rule, they had lost a great deal of blood before they arrived at the hospital. The higher mortality after amputations may be thus accounted for. The average number of days in the hospital is 1.43 less for the amputation cases. This is so little, however, that it offers no argument against conservatism.

As the saving of time is a very important element in operating on severe and multiple injuries, synchronous operations should always be done when one has an assistant who has sufficient training to do one of the indicated operations properly and expeditiously. I found this synchronous method of operating materially reduced the mortality in my own cases.

RESULTS AND SEQUELÆ OF SEVERE MULTIPLE INJURIES.

Of the cases the statistics of which have just been given, only 20 of the conservatively treated are recorded as unimproved—2268 were cured—that is, restored to usefulness, and 777 were improved—that is, restored to partial but not complete function. As noted, the average stay in the hospital was 24.03 days. In most of the cases, while they had their functions sufficiently restored to care for themselves, they were not in a condition to return to their work when they left the hospital. A generous estimate for the period of actual disability would be to double the hospital period; this would make the average time lost from work 48.06 days for each case.

Malingering among working-people (mechanics, miners, and laborers) is very rare. Of over 6000 hospital cases of accidents which have come under my care and observation, I can recall not more than a half-dozen cases of malingering. It is quite another story when it comes to the so-called better classes. I have known many more cases among the "traveling public."

The nearly related ailment, so-called traumatic neurasthenia, which I believe, in the large majority of cases is either conscious or unconscious (subconscious) malingering, is also very rare among working-people. Unimaginative people are usually not subject to these ailments. In my experience nervous, imaginative, "high-strung" individuals are apt to suffer from traumatic neurasthenia after accidents. For a full consideration of the subject, see Vol. II., p. 759.

ACCIDENTS FROM ELECTRIC CURRENTS.

Tesla has shown that alternating electric currents of immensely high potentialities may be safely received by the human body if they be of small ampèrage (small quantity). These currents do not enter the body, but pass over the skin; conversely, currents of comparatively large ampèrage may be safely received if the tension (voltage) is very low. The dangerous currents are those of high voltage and of considerable ampèrage. The ordinary arc-light currents, and currents which serve as motor power for cars of various kinds, are highly dangerous, as they run from 200 to 1000 or more volts, and have variable,

but always high ampèrage, depending upon the power behind the current. Another very dangerous current is that established by short circuiting a strong current—as, for instance, in the case of a man with a monkey-wrench in repairing a switch-board, if he were to allow the metallic end of the handle to come in contact with a terminal while screwing down another one with the wrench, tremendous heat would be developed, a violent flash would occur, the wrench would be suddenly melted, and the man's face and hands would be severely burned. Crossed wires, one of which carries a strong current, produce the same effects.

Electric currents, therefore, produce two varieties of injuries: first, shocks of various severity, and, second, shocks and very severe burns. The immediate effect of a strong electric current is to produce a tetanic contraction of the muscles, so that if a person grasps a live wire, he may not be able to loosen his hold, and on this account he may be held in the circuit of the current until he is relaxed by death. The first thing to do, therefore, in rendering aid to a person who has been or is shocked is to be very sure to remove him from any physical connection with the live wire or whatever other conductor with which he may be in contact. Any one who attempts to remove the person shocked should remember that as long as the current is passing through the body or any member of the affected person this will serve as a conductor for sending the current through the rescuer; the aid-giver may himself be instantly in need of assistance. Of course, when it may be done immediately, or *very soon*, the best thing would be to have the current turned off. This is, however, usually not practicable in time to save the victim, and the shocked man must himself be removed from the current. One who does this should be careful to cover his hands with a silk handkerchief, or put on heavy woolen gloves, or leather gloves lined with wool (rubber gloves are, of course, the best, if they can be had), and be very careful not to stand in a puddle of water or on a wet surface. If the ground is wet (and in any event it is safer), it will be best for him to remove his coat, rapidly fold it, put it on the ground, and stand on this while pulling the man away from the current, with hands well covered and protected as indicated above. The rescuer should be careful not to touch anything metallic (buttons, etc.) about the clothes of the affected individual. He should beware, therefore, of grasping him near his waist and hips, where his pockets are located, as they may contain keys, a knife, or some other metallic article.

TREATMENT OF ELECTRIC SHOCK.

Fortunately, it has been possible, by repeated examination of electrocuted criminals (Kratter,[16] McDonald,[17] Spitzka,[18] Van Giesen[19]), to determine that the histologic effect of lethal currents of electricity is very slight. In a small number of cases a few very slight changes have been found near the third or fourth ventricle of the brain—chiefly small capillary hemorrhages. Cunningham,[20] from his experiments on dogs,

concludes that the current does not paralyze the muscles of the heart. It has been determined also that no chemical change occurs in the nerve-cells of the heart, but that death is due to the disturbance of the coördinating center of the heart. In addition it has been determined that no chemical change occurs in the cells and fluids of the tissues by the action of the strong electric currents.[21]

Crile and McLeod have recently made some experiments which show (see Chapter II., Vol. I., p. 89) "that there is a marked and most important distinction between the cases in which the collapse is due to the passing of the current through the heart muscle, and those in which the current passed through the inhibitory mechanism." These observers noted "that when the heart action was stopped—as would very readily occur—by passing a strong electric current through the vagi nerves, the animal could readily be resuscitated; when, however, the current passed through the heart itself, no effort at resuscitation availed." They further noted "that when a physiologic dose of atropin was administered before the current was turned on, thus paralyzing the inhibitory filaments of the vagi in the heart, the inhibitory effect of the current was almost wholly obviated."

All these observations and experiments go to establish the following practical facts: First, powerful tetanic spasms of all the muscles occur through the violent irritation of both the afferent nerves and of the muscular tissue itself. Secondly, no markedly harmful histologic change is produced in any case, and in the majority of cases no appreciable histologic change is found, and no chemical change in the tissue occurs.[22] Thirdly, the violence and suddenness of the irritation produce very rapid exhaustion of the innervating mechanism of the muscles, and in some cases so disorganize this mechanism that no subsequent coördinate cellular action is possible.

Many cases of shock from powerful currents are, therefore, essentially hopeless from the beginning. It is, however, impossible to determine which these cases are when one first sees them, and, inasmuch as many patients may be resuscitated, one should faithfully try to restore the life of the patient in every case which is seen in time.

Unfortunately, a physician rarely sees a case of collapse from electric shock in time to resuscitate the individual. He may, however, teach men who are exposed to such accidents how to handle them.

The first indication is to restore the respiratory function as soon as possible, at the same time endeavoring mechanically to stimulate the heart. These two indications may be met by laying the person down on his back, placing a rolled-up coat, a small log, or any other convenient rounded object under him at the level of the angle of his scapulæ in order to bring the heart forward and nearer to the surface; then make firm and rhythmic pressure on the left chest and upper part of the abdomen in order to press upon the ventricles of the heart, as well as the walls of the thorax. The tongue should be drawn outward and upward, and it should also be drawn rhythmically forward and pushed backward—not more frequently than twenty times a minute—in order

to assist in establishing respiration. Artificial respiration should be employed for at least an hour before giving up any case as hopeless. Hypodermic injections of atropin, nitroglycerin, camphor, and spartein may also be of service. Strychnin and digitalis, I think, are contraindicated. I have found that shocked individuals have a sensation of cold. Spitzka has shown, however, that the muscular and surface heat in electrocuted individuals is very high, especially in the neighborhood of the electrode placed on the leg. Nevertheless, the indication certainly is to apply external heat by hot-water bags, hot bricks, etc., and blankets. After partial restoration the patient may have a rigor and vomit; one should watch for the vomiting, and be ready to turn the patient so that the vomited matter shall not get into his larynx. After a shock, the injured man, even if he were not made unconscious, is very much "shaken" and feels weak and nervous for some time. Workers in electricity are accustomed themselves to perform a sort of personal artificial respiration after a shock, by raising their upper extremities and lowering them time and again while taking long full breaths. A very intelligent and very experienced workman informed me that he could usually return to his work after a shock if he did this, unless he were made absolutely unconscious. He would feel weak and shaky the balance of the day, however, and he would frequently have a headache. A single personal experience with a heavy shock, which knocked me over and produced momentary unconsciousness, caused the feeling and left me in the condition detailed by the old electrician, noted above.

Persons who have been resuscitated from collapse and those who have endured heavy currents should rest absolutely for a time. They should be given no food except, perhaps, some hot broth or bouillon, for a number of hours. Hot black coffee is useful as soon as it can be swallowed and retained. A mild sedative may be necessary for two or three nights to procure sleep for a nervous individual.

Burns produced by electric currents are usually intractable and very slow to heal. They should be treated as any other deep burn.

ACCIDENTS FROM GASES.[1]

The two cases which produce accidents in home life are, first, coal-gas, carbon dioxid (CO_2), and, second, carbon monoxid (CO). These gases may be introduced into a living apartment or bedroom from a defective flue or improperly managed hot air-furnaces, or from stoves, especially the latter.

Carbon dioxid (CO_2) is a purely negative poison, and is injurious because it cuts off oxygen from the lungs. By freely opening all windows and doors and allowing the gas to escape, or by carrying an asphyxiated person out into the fresh air, if the reflexes are not abolished, recovery is prompt. If the reflex respiratory stimuli no longer act, then artificial respiration should be resorted to, and in extreme cases bleeding may be employed and the blood extracted be replaced by an equal quantity of saline solution introduced into the vein at a tem-

[1] See also p. 1223.

perature of 105° F. Oxygen gas may also be used by inflation. Strychnin and atropin sulphate given hypodermically will be of service when the respiration has been partially established.

Asphyxiation from carbon monoxid (CO) is an extremely dangerous condition, and one very difficult to treat successfully. This gas comes from burning coal or coke directly in a room, as a rule, or from illuminating gas. The hot coals, and sometimes red-hot porous cast iron, will take up an atom of oxygen from the CO_2, and discharge CO into the atmosphere. This gas is a direct and virulent poison. It causes rapid destruction of the red corpuscles. Measures of relief must be directed toward not only obtaining pure fresh air for the asphyxiated person, but also for forcing air into his lungs by artificial respiration, and especially by inflation of oxygen under pressure into his trachea. A quantity of the vitiated blood should be withdrawn by venesection and be replaced by transfused blood from a healthy person if possible, or, failing this, saline infusions may be used to replace the blood. After the "attack," the patient will be very weak and pale and will require careful restorative treatment.

ACCIDENTS FROM ILLUMINATING GAS.[1]

The modern method of manufacturing illuminating gas from the decomposition of water and the addition of petroleum compounds has resulted in the furnishing of a very impure quality of gas, highly charged with carbon monoxid (CO). This is a very dangerous product. Asphyxiation from this water-gas is, as a rule, very deadly. Exposure to pure fresh air, inhalation of oxygen, artificial respiration, and, in short, the same treatment as recommended above for carbon-monoxid gas poisoning should be emp'oyed. The hypodermic use of strychnin and atropin must also be vigorously employed, according to the severity of the poisoning.

In the "American Journal of the Medical Sciences" (October, 1907) Crile also recommends infusion of blood, by his direct method of infusion, for treatment of poisoning by illuminating gas.

Dr. J. Chalmers Da Costa published in "The Therapeutic Gazette" (March, 1903) a paper on "The Effects of the Inhalation of Smoke," etc., to which I wish to refer. This paper deals with the effects and treatment of the inhalation of smoke and fumes of acids and ammonia.

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CHAPTER LXXVIII.

SURGERY OF THE PARATHYROID BODIES.

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History.—Very little has been added to our knowledge of the structure of the parathyroid glandules since the careful description of their anatomy and histology by Sandstroem[1] in 1880. The name "glandulæ parathyroideæ," which he gave to these organs, has since been generally accepted. Following Sandstroem, Rogowitz,[2] Christiani,[3] Zielenska,[4] and Hürthle[5] respectively described in various animals glands which were evidently parathyroids, but which they considered embryonic thyroid tissue. In 1895 Kohn,[6] under the term "epithelial capsules," noted the presence of 4 parathyroids per individual in the cat, dog, and rabbit. Schaper,[7] in 1895, reported his observations on 5 cases in man, in 1 of which he found 6 parathyroids. Müller,[8] in 1896, reported on the examination of 92 cases in man, besides certain laboratory animals.

An exhaustive paper by D. A. Welsh,[9] in 1898, gave a full analysis of the anatomy and histology of the parathyroids. He found, in nearly all of 40 cases in man, two glands on each side, which he named according to their position as "posterior superior" and "anterior inferior." He described also two types of cells, "principal" and "oxyphil," and four types each of their various arrangements. Schreiber,[10] in 1898, reported that, embryologically, the parathyroids develop from a single symmetric anlage whose epithelial cell-masses are subsequently separated, forming two or more pairs of glands.

During the last decade a great number of writers have contributed evidence as to the number, location, blood-supply, etc., of the parathyroids in man. (See Bibliography, Nos. 11 to 19.)

Concerning our knowledge of the function of the parathyroids we are indebted to Gley[20] for the suggestion that the removal of the parathyroids is the cause of the tetanic symptoms occurring in animals after thyroidectomy. His work has been confirmed by many authors. (See Bibliography, Nos. 21 to 38.)

Moussu[30] is responsible for the unsupported hypothesis that parathyroid insufficiency is the cause of exophthalmic goiter, while a number of authors, including Moussu,[30] Vassale and Generali,[31] and Jeandelize,[29] have suggested that various convulsions may be due to degeneration or absence of the parathyroids. Lundberg[34] advanced the hypothesis that paralysis agitans is due to the same cause. This latter

hypothesis, however, has been shown to be unsupported by Thompson[40] in a careful study of 9 cases.

The work on the transplantation of the parathyroids will be referred to later.

Anatomy.—The parathyroid bodies are ovoid organs, usually four in number, situated on the posterior surface of the lateral lobes of the thyroid gland in two pairs, superior and inferior. Thompson and Harris[19] find at least four glandules in 90 per cent. of routine autopsies (Figs. 442, 443).

The superior pair lies against the posterior wall of the esophagus, somewhat above the level of the lower edge of the cricoid cartilage,

FIG. 442.—SHOWING POSITION OF VESSELS AND ROTATION OF GLAND OVER AND ACROSS TRACHEA. POSTERIOR CAPSULE IN THE FIELD OF VESSELS. (Drawn by Miss Florence Byrnes for Dr. C. H. Mayo.)

internal to the posterior border of the lateral lobe of the thyroid gland and anterior to the prevertebral fascia. They are usually behind the lateral thyroid ligaments, though this relationship is far from constant. While the height is usually as above stated, this pair of glands may be found as high as the inferior horn of the thyroid cartilage, or as low as the tenth tracheal ring.

The inferior pair is commonly more anteriorly placed than the superior. They usually lie against the sides of the trachea, near the ends of the rings, under cover of the lower end of the thyroid. They always lie in front of the inferior thyroid artery; they usually lie as low as the tenth tracheal ring. Halsted[48] (Fig. 443), by means of a

composite chart based on 67 dissections, has shown that the parathyroids may be found at any level from the superior to the inferior pole on the postero-internal surface of the thyroid, most commonly just internal to the rounded postero-external border, and quite regularly near the site of the distribution of the terminal branches of the inferior thyroid artery. Occasionally a third pair of glands is found, usually placed lateral to the line of the middle pair and well below them. Rogers and Ferguson[15] call attention to the occasional occurrence of considerable parathyroid tissue, found in string-like masses along the lateral margins of the thyroids. From the above facts is apparent the extreme difficulty in determining with any degree of accuracy, in either the dead

FIG. 443.—SHOWING BLOOD SUPPLY AND ANASTOMOSIS OF VESSELS. Parathyroids behind capsule. Trachea sectioned, showing the recurrent laryngeal nerve. (Drawn by Miss Florence Byrnes for Dr. C. H. Mayo.)

or the living subject, the total amount or the entire absence of parathyroid tissue.

Halsted[48] finds no difficulty in identifying the parathyroids with the naked eye in the course of an operation. While this may be true of the more marked glands, it seems to me almost impossible to differentiate small, eccentrically placed, unusually colored glands from accessory thyroids, fat, and lymphatics, without histologic examination. This accords also with Rogers and Ferguson's experience, who found that of 189 pieces of human tissue removed as presumably containing parathyroid glands, only 61 pieces, or 32 per cent., were shown by microscopic examination to contain this organ.

The parathyroids are apparently always separated from the thy-

roid by a capsule, though occasionally they are found imbedded within more or less completely closed invaginations of the thyroid capsule.

Evans[49] has made a careful study of the blood-supply of the parathyroids, and summarizes his observations as follows:

"(1) The parathyroid glands are always supplied by definite parathyroid arteries which enter them in each case at the hilus.

"(2) The parathyroid arteries, superior and inferior, usually arise from the inferior thyroid, but frequently they take their origin from the anastomosing channel between the inferior and superior thyroid vessels (Halsted's 'line of anastomosis').

Fig. 444.—Posterior View of Thyroid Gland. (Ginsburg.)
Anastomosis between vessels of parathyroid bodies on sides: *A.*, Anastomosis in posterior surface of pharynx; *S. T. A.*, superior thyroid artery; *S. P. B.*, superior parathyroid body; *I. P. B.*, inferior parathyroid body; *R. L. N.*, recurrent laryngeal nerve. (Reduced one-sixth natural size.)

"(3) Few, if indeed any, direct vascular connections normally exist between the parathyroid glands and the connective-tissue envelopes of the thyroid" (Figs. 444, 445).

Ginsburg calls attention to the secondary accessory blood-supply for the parathyroids through the anastomotic channels from the thyroid arteries of the opposite side, and suggests that, since the ligation of both the superior and the inferior thyroid *outside* the capsule would not disturb the blood-supply through this anastomosis, we may thus have the explanation of the failure of tetany to develop in certain cases of bilateral thyroidectomy.

The glands are usually 6 or 7 mm. long, 3 to 4 mm. wide, and 2 to 5

mm. thick, though all of these dimensions may vary greatly. Their usual weight is about 0.035 gm., though they may weigh as much as 0.2 gm. From the varying amount of fat and blood which they contain their color varies from light creamy yellow to dark reddish brown. Often they may be distinguished by their color contrasting with that of the surrounding tissue. The surface is smooth, each gland being covered by a delicate fibrous capsule which subdivides it into lobules. The connective tissue of the septa supports the blood-vessels and, finally, subdivides the lobules, usually into anastomosing columns of densely packed epithelial cells.

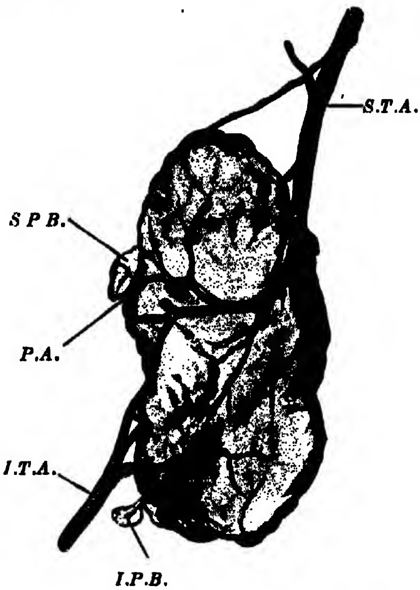

FIG. 445.—LEFT THYROID LOBE VIEWED FROM BEHIND. (Ginsburg.)
Shows unusual position and blood supply of superior parathyroid body, rendering body likely of removal in lobectomy: *S. T. A.*, Superior thyroid artery; *S. P. B.*, superior parathyroid body; *P. A.*, parathyroid artery; *I. T. A.*, inferior thyroid artery; *I. P. B.*, inferior parathyroid body. (Reduced one-sixth natural size.)

Histology.—The cells are of two types, spoken of as "principal" (Fig. 446) and "functional." The former are relatively small cells, with large, deeply staining nuclei and feebly staining cytoplasm. They constitute the bulk of the gland, and while they may vary in shape, size, and staining properties, size of the nucleus, etc., they are always readily recognizable. They are sometimes distributed with no distinct lobulation, being packed irregularly and in direct contact with each other, thus assuming polyhedral shapes. In some areas the principal cells are arranged much like those of the thyroid, forming definite acini which may contain colloid material.

The so-called "functional" (Fig. 447) cells are considerably larger than the principal cells, and consist of readily stainable acidophilic granular cytoplasm and small, densely staining nuclei. They are much less numerous than the principal cells, and, indeed, may be entirely absent

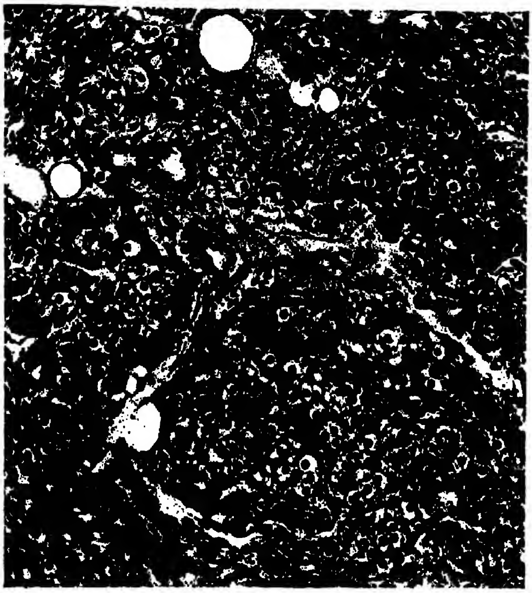

Fig. 446.—Principal Cells. (After E. H. Pool.)
(Photomicrograph reproduced from "Tetany Parathyreopriva.")

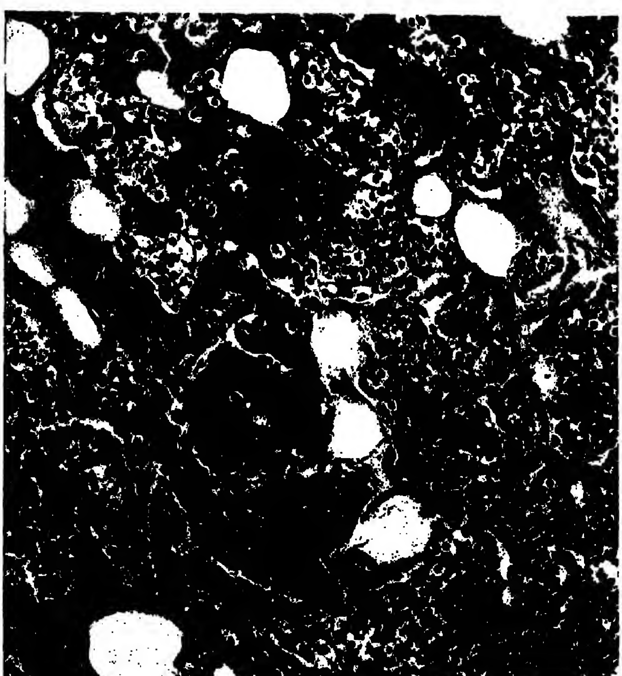

Fig. 447.—Masses of Oxyphile Cells. (After E. H. Pool.)
(Photomicrograph reproduced from "Tetany Parathyreopriva.")

from a given gland. When present, they are usually in small islands containing, in section, three to twenty cells, each scattered irregularly

throughout the gland. Occasionally they make up acini or short columns.

The glands may then be conceived of as small, grape-like clusters of fat-laden epithelial cells, with a fairly good vascular supply, held together, for the most part, by exceedingly delicate membranes, and arranged in some areas as irregularly as the cells of lymph-nodes and in others as definitely grouped as those of the thyroid.

Embryology.—The parathyroids develop from the third and fourth pairs of the branchial clefts. Initially, they are small, well-marked-off masses of cells, completely segregated from the thyroids. There is little to indicate that the parathyroids are embryonal thyroid tissue, as has been supposed. The glands become attached to the thyroid only secondarily in the course of their development.

Physiology.—The study which these glands have received recently has materially changed our ideas concerning their chemistry and physiology. Most writers up to three or four years ago state definitely that the parathyroids contain a large percentage of iodin. Recent observers, however, discredit this, many of them going so far as to state that in man, at least, iodin may be entirely absent from the gland, and suggesting that the observations previously made may have confused accessory thyroids with parathyroids. The statement that the gland contains a considerable quantity of colloid must also apparently be modified, since the evidence of the presence of colloid usually rests upon a staining reaction only. Some recent observers fail to find any colloid whatever in the gland. It would appear not improbable that when it is present in the acini of the gland, it may be considered as a retention complement.

When the parathyroids are all removed from a carnivorous animal, it usually quickly dies of tetany. On the other hand, when the glands are all extirpated from herbivorous animals, in a large number of instances no untoward symptoms whatever appear. This marked disparity of results in the two groups of animals has been explained on the hypothesis that parathyroid tissue may be more widely distributed in the herbivorous group than in the carnivorous, and hence its complete removal be rarely or never accomplished. It seems more probable, however, that the parathyroids are not so essential to metabolic equilibrium in the herbivora as in the carnivora. Indeed, there is a possibility that this may be true in man—an omnivorous animal—as well as in the herbivora. There are some cases on record of the apparent complete removal, *e. g.*, during the thyroidectomy for carcinoma, of all of the parathyroids, without the subsequent development of any tetanic symptoms. On the whole, the function of the gland seems to be the elaboration of an internal secretion, which, carried to the tissues by the lymph- and blood-stream, assists in preserving metabolic equilibrium either by supplying an essential stimulant to some other glands or organs, or by neutralizing some absorbed toxins or excessively produced secretions. This latter hypothesis would seem to be supported by the frequently repeated observations that tetany of parathyroidectomized

animals may be temporarily relieved by free bleeding, and copious injections of salt solutions.* MacCallum and Voegtlin[50] have shown that in the parathyroidectomized dog, during tetany, the calcium content of the blood is only about one-half that of the normal dog on the same diet. They suggest the working hypothesis that "the parathyroids control in some way the calcium metabolism, so that upon their removal a rapid excretion, possibly associated with inadequate absorption and assimilation, deprives the tissues of calcium salts." They have been able temporarily to control tetany in the dog by the administration of calcium salts (acetate and lactate) in 5 per cent. solution intravenously or by stomach.

Pathology.—Like other glands, the parathyroids are subject to parenchymatous hyperplasias, cystic and fatty degenerations, fibrous and fatty infiltrations, etc. Thompson and Harris[19] have collected the bibliography of various pathologic changes. (See Bibliography, Nos. 51 to 75.)

A careful study of their summary seems to show that so far no relationship has been traced between pathologic changes in the parenchyma of the glands and any symptoms the patient may have exhibited during life.

Surgery.—Our knowledge of the parathyroids has been derived from accidental findings through their injury in operating for goiter and from experimen al work. This would indicate that these bodies are remarkably free from diseases which require surgical treatment. Da Costa,[89] in reporting an operation for hyperplasia of the parathyroids, also reported 7 other cases, all of hyperplasia or adenomatous growths, 5 of which were found at autopsy.

Since a microscopic examination is necessary in order to differentiate the parathyroid from the thyroid tissue, it is possible that some of these former bodies have been removed as goiters. It is probable, also, that with the greater increase of surgical treatment of the thyroid we shall soon have more reported cases of parathyroid tumors.

Indirectly, the parathyroids are of great surgical importance from the possibility of their injury or the cutting off of their blood supply (Halsted[76]) during operations upon the thyroid gland. While tetany may follow various diseases and infections, when it appears after an operation upon the thyroid it will indicate injury to these bodies or the loss of parathyroid secretion. In the description of such a case of tetany Pool[30] corroborates that given by Frankl Hochwart[77] that "tetany parathyreopriva" is characterized by certain very striking symptoms which render it practically unmistakable. The most conspicuous of these are intermittent tonic spasms of the voluntary muscles, those of the extremities being most effected. A salient feature is the exclusive involvement of the flexor groups of muscles. Intercurrent contractures of the fascial muscles are relatively rare, and the muscles of the chest, back, and abdomen participate in exceptional cases only. The tetanic spasms are usually preceded by certain prodromata which persist for a variable period before the onset of the attack. These include headache, sensations of weakness or prostration, more or less rigidity of the limbs,

* See postscript on page 961.

radiating pains, and clonic twitchings. The contractions usually begin in the hands and subsequently involve the feet; less often the feet are effected coincidentally or independently. The spasms are almost always symmetric and bilateral. As a rule, two or more of the fingers are flexed and the thumbs are forcibly abducted, sometimes tightly clasped by the contracting digits. In 50 per cent. of these cases the wrist also becomes flexed, while flexion of the forearm, with abduction of the arm to the trunk, occurs infrequently. Exceptionally, the fingers are held wide apart, the terminal phalanges alone being flexed. The feet, when involved, take the position of pes equinus or equinovarus, as a result of contraction of muscles of the calf. In the contractions of tetany the affected muscles become very hard to the touch and oppose a powerful resistance to attempts at passive relaxation. Should this prove successful, the tetanic attitude is at once resumed when the traction diminishes. Fibrillary twitchings are sometimes visible in the contracted muscles. The duration of an attack may not exceed a few minutes or the attack may last for a number of hours, but it rarely persists as long as forty-eight hours. The termination of a tetanic spasm is frequently preceded by symptoms resembling those observed at the onset.

While there may be a free interval of days or weeks between the attacks, unfortunately this is far from being the rule. There are generally several attacks in the course of a day, whereas the patient's rest at night is unbroken. In the severest cases one attack follows another with alarming rapidity.

Trousseau[78] assumes three distinct degrees of tetany based upon the distribution of the spasms: first, a mild form, affecting the peripheral muscles only; some of these attacks may even be limited to the hands; second, a moderate form, with involvement of the facial, abdominal, and trunk muscles; third, a severe form, extending to the involuntary muscles.

Besides the attacks of spasms, there are other manifestations of the disease. Certain disturbances of sensation are regularly present, especially pain, which is a constant concomitant of the spasms. Hyperesthesia, paresthesia, or anesthesia also may be noted. Temporary redness and edema are not infrequently observed over the joints. Trophic and secretory anomalies, such as sweating, loss of hair, and changes in the nails, are not very uncommon.

Of particular significance as bearing on the diagnosis are the tests of Chvostek, Trousseau, and Erb.[79] In two-thirds of all cases of tetany it is possible to demonstrate Trousseau's phenomenon. This consists in the occurrence of a tetanic spasm in a limb as the result of compression of its main vessels and nerve-trunks. By the animal experiments of Frankl Hochwart and Kashida this phenomenon has been shown to depend upon the stimulation of the nerves.

Chvostek pointed out the facial phenomenon which can be elicited in tetanic patients by gently tapping over the area of distribution of the facial nerve. The resulting short twitchings are known as Chvos-

tek's symptom, which is especially valuable by reason of the simple technic required for its demonstration.

Erb called attention to the fact that electric hyperexcitability of the motor nerves is regularly present in these cases. There is a marked increase of galvanic irritability, especially in the ulnar nerves, whereas an increased reaction to the faradic current is far less constant. The value of the two tests, dependent upon stretching the nerves of the brachial plexus and the sciatic nerve, cannot be estimated properly until repeated trials have been made in further cases.

The tendon reflexes are normal or increased. A certain number of cases—too numerous to be interpreted as an accidental coincidence—present a combination of tetany with typical epileptic seizures. These symptoms have sometimes been observed after thyroidectomy in individuals previously free from nervous symptoms, and a possible connection between epilepsy and tetany has accordingly been suggested. Certain authors also include among the symptoms of tetany the hysteric attacks which are occasionally present (*cf.* Frankl Hochwart).

The course of tetany following thyroidectomy has been divided by Frankl Hochwart into three classes: "First, cases characterized by onset soon after operation, severe course, and fatal outcome; second, cases in which the symptoms appear soon after operation, but subside after a variable time and are followed by recovery; third, cases in which the patients live and symptoms of myxedema become associated in variable degree with those of tetany."

In the treatment of tetany following goiter operations the administration of the thyroid and parathyroid glands and their products has been thoroughly tried. Improvement of the symptoms of tetany have been noted by Hoffman,[80] Levy-Dorn,[81] Westphal,[82] and others following the feeding of thyroid, while Lowenthal and Wiebrecht[83] believe the good results obtained were from feeding the mixed glands—thyroid and parathyroid. Most observers have seen no results from this treatment. Temporary relief has been obtained by venesection followed by infusion of saline solution.

Serum treatment (Beebe's[84]) has been spoken of, notably by Halsted, in reporting a chronic case of tetany as favorable but transient. The same patient was previously treated by feeding dried parathyroids of beeves. Later these were substituted for fresh glands. He says: "Their exhibition was by mouth only, as prolonged hypodermic administration of the crushed glands could not, it seems to us, be endured, owing to the physical properties of the emulsion, the bulkiness of the dose, and the annoyance and danger from the hardly avoidable infection. The patient promptly discovered, as did we, that the dried glands, a nauseous dose, seemed less effective than the fresh.

"In preparation for ingestion the fresh glands were carefully freed from fat, chopped very fine, and served on thin, crisp water-crackers. The dried powdered glands were usually given in gelatin capsules."

Transplantation of the parathyroids has been under experimental study for some time, with a varying degree of success. Payr[44] shows

that the tissues which have only internal secretion are the best for transplanting. Parenchymatous organs in whole or in part have been successfully transplanted in animals of the same species. The transplanting of such tissues into animals of different species, and from animal to man, has not been successful. The tissue is absorbed, the temporary results obtained being due to this process.

Christiani[22] states that, when it is necessary to preserve for a brief period tissue to be transplanted, it should be in the serum of the same species of animal, since salt solution, used for this purpose, is toxic.

There has been considerable discussion as to the best site for the implantation—subcutaneous, extraperitoneal, and intraperitoneal, omentum, or spleen. Payr[44] has shown in several cases both thyroid and parathyroid tissue living after a considerable period imbedded in the spleen. Leischner[45] has been successful in transplanting them preperitoneally in rats. Pfeifter, Herman, and Mayer[46] succeeded twice in puppies.

Pool, who has experimentally transplanted the parathyroids in rabbits and dogs, questions whether the limited number of good results could have come from that cause. There is always the possibility of existing accessory parathyroids.

Halsted[85] has given a brief summary of his experimental work as follows:

"Transplanted parathyroids (autografts) may, for an undetermined time, perform at least the most evident function of these bodies.

"One successfully transplanted parathyroid may suffice to maintain a fair degree of health; traces of hypoparathyroidism may persist.

"In autotransplantation success is more common than failure.

"Heterotransplantation rarely succeeds.

"For the successful transplantation of these organs a deficiency of parathyroid tissue should be created.

"Transplanted in excess of what is required by the organism, parathyroid glands do not survive.

"Excised or deprived of their blood supply in the course of an operation parathyroids should probably be reimplanted, preferably into the thyroid gland.

"Complete excision of the thyroid lobes is well borne for months, at least, by animals. Myxedema begins to manifest itself in a few weeks."

From experimentally produced tetany in dogs, MacCallum and Voegtlin[86] recommend the administration of lactate of calcium for immediate relief until the parathyroids of animals can be transplanted. The dosage of lactate of calcium for dogs as given by them is 50 to 100 cc. of a 4 per cent. solution by mouth, or 10 cc. of a 5 per cent. solution intravenously.

From what has been presented, the unsettled condition of our knowledge of the parathyroids is quite evident; and yet order is beginning to appear. To judge from the variation in the number, size, position, and blood supply of the parathyroids, one would think that nature has varied from her usual care in regard to such matters, as manifested

in other organs of much less importance. However, the lesson to be learned is similar to that already settled concerning the thyroid—*i. e.*, (1) to leave part of the thyroid to prevent myxedema, and (2) to preserve uninjured at least half of the parathyroids, and all if possible. Since the risk occurs only in goiter operations, we must consider what is the safest type of operation upon the thyroid.

In our operative experience of over 1000 goiters we have seen no tetany. Many of these operations were performed before the importance of the parathyroids was known, and it is possible that the operative methods employed tended to their preservation.

In discussing the technic of thyroidectomy I have called attention to the importance of preserving the posterior capsule.[86] During thyroidectomy in 4 cases where only one parathyroid was removed, there were no symptoms, either immediate or late, that could be attributed to this cause.

In operating for the relief of goiter the surgical procedures which might injure the parathyroids are: (1) ligation of arteries in the treatment of early or mild cases of Graves' disease, and in the more severe forms of hyperthyroidism as a graduated operative procedure; (2) thyroidectomy.

The free anastomosis of vessels in the thyroid with the active and excessive circulation which is characteristic of hyperthyroidism renders such injury improbable. This is also true of the extirpation of one lobe and the isthmus in exophthalmic goiter if the posterior capsule is preserved by incising it along the lateral border of the thyroid gland, brushing it back with gauze and applying forceps to the numerous vessels which enter the capsule and are seen as the gland is rotated over the trachea. The same method is employed in operating for colloid goiter where extirpation of one lobe is advisable.

If both lobes of the gland and isthmus require reduction, the extirpation method should be applied only on one side, the remainder of the gland being reduced by some form of partial enucleation or resection as advocated by Mikulicz, who resected both sides with approximation of the gland tissue, hemorrhage control being secured by a locking suture. Apparently the greatest risk of hypoparathyroidism is from secondary operations upon the remaining enlarged lobe following a previous extirpation of one lobe of a colloid goiter.

In the rounded encapsulated adenoma or cyst tumors of the thyroid the surgical indications are for enucleation of the tumors with as little injury to the surrounding tissue and thyroid gland as possible. In operating according to this method there need be no fear of parathyroid injury.

Operation upon the parathyroid bodies, which will nearly always be undertaken in the belief that the operation is for goiter, requires the same incision, exposure, and care as in an operation for goiter (Fig. 448).

A criticism that can be quite generally applied to all surgery of the neck is that severe and desperate procedures are often undertaken

through small and badly placed incisions, and that the operation is advanced until the simple technic becomes complicated in an effort to save structures which are of little importance and which could be easily readjusted if interfered with.

We prefer the transverse collar incision with elevation of the unseparated skin and platysma muscle sufficient to expose the sternal attached

FIG. 448.—ENUCLEATION OF GOITER.

muscles. A vertical incision separates the hyoid muscle in the midline to the thyroid body.

These muscles may be severed above their nerve supply opposite the thyroid cartilage on one or possibly both sides, should it be advantageous to secure free exposure.

Section of one sternohyoid muscle above is usually sufficient to facilitate the dissection of the upper pole of the thyroid and permit the careful ligation of the superior thyroid artery. It is from this artery after goiter operations that secondary hemorrhage usually

occurs, and it is due to muscle fibers being included in the ligature (Fig. 449).

During operation it is best to preserve all small gland-like masses found about the capsule of the thyroid, as they may be parathyroids. If a parathyroid body is removed, it should at once be implanted beneath some part of the capsule of the remaining thyroid. After some experience the operator may identify many of the glands at sight.

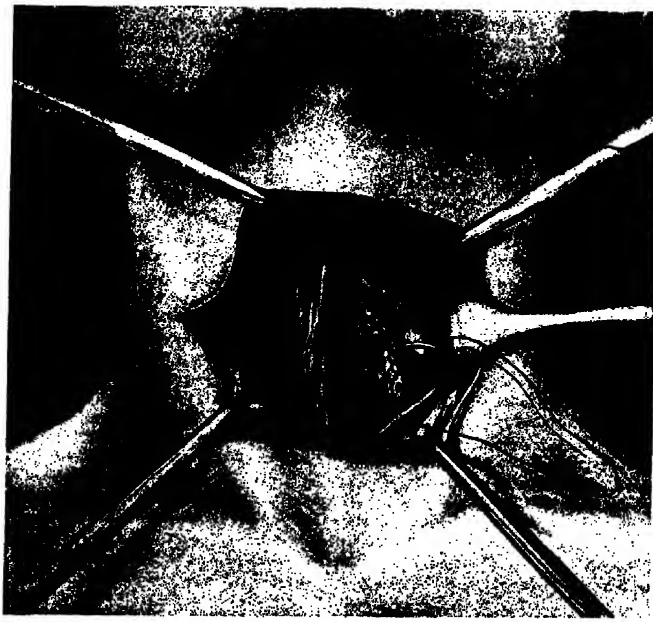

FIG. 449.—SHOWING MUSCLE SUTURE NEAR ATTACHMENT AND INTERLOCKING SUTURE OF CUT GLAND.

Wounds are, as a rule, temporarily drained. The incisions are closed by subcuticular suture of platysma and skin.

Operations are preceded by $\frac{1}{150}$ gr. solution of atropin with $\frac{1}{8}$ gr. solution of morphin. Ether given by the open method is the anesthetic preferred, although cocain may occasionally be indicated for various reasons.

While this chapter was in the hands of the printer, Kocher[90] published the transplantation of thyroid tissue in the tibia of a dog previously parathyroidectomized. The animal showed no symptoms of tetany when the transplanted tissue was removed.

Thompson, Leighton, and Swarts[91] have repeated and confirmed Kocher's experiment, and in addition apparently prevented tetany in parathyroidectomized dogs by packing the opening in an animal's tibia with cotton wet with bichlorid of mercury. These experiments, along with the observations of Vincent and Thompson (Mrs.)[92] on a comparative embryology and physiology of the thyroid, would seem to reopen the whole question of the related function of these two glands.

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CHAPTER LXXIX.

THE INTRACRANIAL SURGERY OF THE FIFTH (TRIGEMINAL) AND THE EIGHTH (AUDITORY) NERVES.

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PHILADELPHIA.

I. THE TRIGEMINAL NERVE (N. TRIGEMINUS).

In a consideration of the intracranial operations upon the fifth cranial nerve (N. trigeminus), it is assumed that we have to do only with the major or epileptiform neuralgias, at least for the most part, bearing in mind, however, that by pressure or infiltration a neighboring tumor of the brain or skull may so involve the ganglion of Gasser as to require surgical intervention if only to afford temporary relief. The intracranial operations are called for when the symptoms indicate the involvement of more than one division, and when the frequency and severity of the paroxysms bespeak the gravest type of the disease, and are undertaken usually when other measures have been tried and failed. The majority of patients presenting themelves for operation are past middle life, and usually have submitted to various methods of treatment, including the administration of internal remedies, the extraction of teeth, the treatment of suspected sinus disease, alcohol injections, and a number of peripheral operations. They are worn out with intense suffering and sleepless nights, are poorly nourished, and often addicted to the use of morphin or alcohol in large quantities. While often not the most favorable subjects for operation, nevertheless, by the avoidance of hemorrhage, shock, and infection, the chances of immediate recovery with absolute and complete cessation of symptoms are greater than after a great many other major operations.

As to the pathogenesis of trigeminal neuralgia there is no unanimity of opinion. Excluding primary or secondary involvement of the ganglion by malignant tumor, there are a number of instances of genuine major neuralgia in which demonstrable lesions of the ganglion or its divisions have been conspicuous by their absence. On the other hand, certain cellular changes have been found in the ganglion of patients suffering from tic douloureux, while precisely the same changes have been found when tic douloureux did not exist (Caminiti). The disease may be of central origin—that is, from a lesion in the pons, in the sensory root, or in the ganglion itself; the ganglion may be involved primarily or secondarily to diseases of the peripheral branches. In a

word, there remains to be found a lesion, either central or peripheral, which is either constant or characteristic. This view is held by such authorities as Spiller, Hutchinson, and Krause.

Historic Note.—A quarter of a century ago Dr. J. Ewing Mears, of Philadelphia, advocated extraction of the Gasserian ganglion for intractable cases of tic douloureux. While this proposal was made in 1884, the first successful operation was performed by Rose in 1890 and repeated in 1891, and in the same year Horsley, failing in an attempt to remove the ganglion, avulsed the sensory root, but the patient did not survive the operation. Since that time a number of important contributions to the subject have been made, and by a process of evolution and elimination a technic has been elaborated and so perfected that the operation, far from being the dangerous and hazardous procedure of a decade ago, is attended with a mortality quite as low as, if not lower, than many other of the more common major surgical procedures. The reduction of the mortality is in large measure due to the fact that it has been found unnecessary to remove the ganglion *in toto*. It is interesting to see how, chronologically considered, the steps of the operation have been simplified. At first it was thought best to remove the ganglion *in toto*, and the unsuccessful attempts in the early days were responsible for many cases of so-called recurrence. Later on some surgeons advocated the removal of only the outer and posterior portion of the ganglion (Horsley, Hutchinson, Jr.); still later, the division of the second and third divisions, with the interposition of foreign material to prevent regeneration, was proposed (Abbe), and, finally, Spiller proposed the division or avulsion of the sensory root, leaving the ganglion wholly intact. While the foundation stone was laid by Mears in 1884, the keystone of the arch was set in 1901 when Spiller proved that if once it is divided the sensory root would not regenerate itself. This may be said to be the last consequential contribution to the development of the technic of the central operation.

Anatomic Consideration.—No operation demands a greater familiarity with the anatomic relations, and especially with the frequent variations from the normal. The ganglion itself is situated on the apex of the petrous portion of the temporal bone in the cavum Meckelii. To its inner side will be found the cavernous sinus and the third, fourth, and sixth cranial nerves (NN, oculomotor, trochlearis, and abducens), of which the latter bears the closest relation, and is, therefore, most exposed to trauma (Fig. 450). The ganglion itself is somewhat crescentic in form, measures approximately 2 by 1 cm., and is enclosed in a special dural sheath (dura propria). The latter must always be incised and reflected before the ganglion itself comes into view. Generally speaking, the dura propria adheres firmly to the underlying ganglion, but at a point where the superior maxillary division enters the foramen rotundum it is most easily separated. The blood-supply of the ganglion is derived from a branch of the middle meningeal artery and a small branch of the internal carotid artery. They enter the ganglion from its under surface; consequently, in attempts at extraction, the most profuse and

troublesome hemorrhage is not encountered until the attempt is made to dislodge the ganglion from its bed. The foramen spinosum, through which the middle meningeal artery penetrates the base of the skull, is to the outer side of the ganglion, sometimes anterior, sometimes posterior to the foramen ovale. In an examination of some fifty skulls, Arnyx called attention to this great variation in the course of the middle meningeal. In some instances he found it between the foramen rotundum and foramen ovale; in some it was not present at all, and in some it was found internal to the foramen ovale. Bartlett and Döllinger have also observed this variation between the foramina spinosum, ovale, and rotundum. In 6 per cent. of his cases Döllinger found the foramen spinosum in front of the anterior border of the foramen ovale,

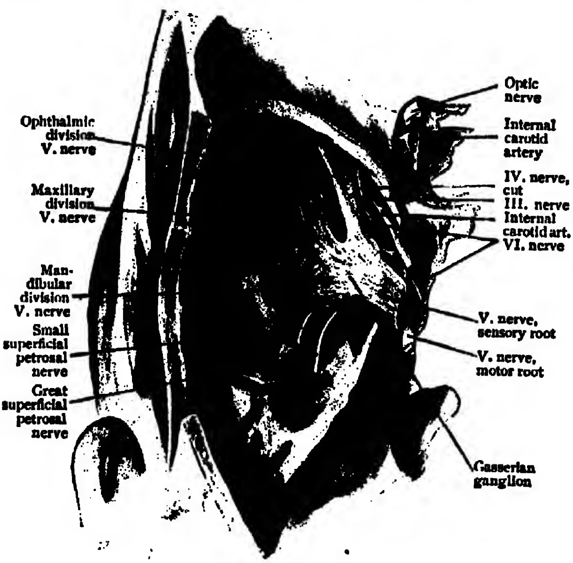

FIG. 450.—GASSERIAN GANGLION OF LEFT SIDE VIEWED FROM ABOVE: SENSORY AND MOTOR ROOTS AND THREE DIVISIONS OF TRIGEMINAL NERVE ARE SEEN. (Piersol's Anatomy.)

thus rendering the third branch inaccessible. In the majority of instances, therefore, and this is the practical significance of these anatomic considerations, the middle meningeal artery at its emergence from the foramen interferes with the direct approach to the posterior portion of the ganglion and its sensory root. In order, therefore, to render these accessible it is necessary to ligate and divide the artery.

If, on the other hand, for one reason or another the operator prefers to depend upon the removal of the ganglionic structure as a means of permanent relief, he should be content, providing, of course, the opthalmic division is not involved, with the removal of only the lower portion of it with the second and third divisions rather than attempt total extraction. Both from practical and theoretic considerations, Hutchinson has made out a strong case in favor of this method; in the vast majority of instances only the second and third divisions are

involved, and it has been proved by clinical results that in each instance there will be no recurrence, even though the inner aspect and the ophthalmic division are left intact. In 1905 he had carried out this operation upon 7 patients, and they had been entirely free from recurrence for periods ranging from two to seven years. With this modification of the technic of total extraction (1) there is no anesthesia of the cornea, and hence no risk of loss of the eye; (2) there should be no danger of injuring the oculomotor nerves or of wounding the cavernous sinus; and (3) the severity of the operation is rendered less, the degree of hemorrhage and the chance of injurious pressure on the brain both being materially diminished. Abbe's operation, somewhat similar to Hutchinson's, in that only the second and third divisions are dealt with, does not give the same guarantee against recurrence. As a matter of fact, once the ganglion and these two divisions have been exposed, the most tedious part of the operation has been completed, and after the second and third divisions have been divided at their respective foramina (Abbe) it adds but little to the time and difficulties to remove the adjacent portion of the ganglion (Hutchinson). We have, therefore, apart from other considerations, practically four methods from which to choose; namely, the division of the root, total extraction of the ganglion, extraction of the portion adjacent to the second and third divisions, and simple division of the latter with interposition of some foreign material. Apart from these, there are a number of other important technical considerations, not the least of which is the method of approach.

Method of Approach.—Of these there are a number—viz: the pterygoid route (Rose), now more or less obsolete, the Hartley-Krause or temporal route, still practised, but not so universally, the infratemporal route (Lexer-Cushing), the zygomatic-basal route (Doyen and Quénu), and the auriculotemporal (Frazier). The ideal approach is one which will give an adequate exposure of the ganglion itself without exerting too much pressure upon the brain, one which does not necessitate the division of the upper or temporofacial branch of the facial nerve, and one which causes the least disfigurement. Krause's incision is the only one in which the upper branch of the facial nerve is seriously exposed to injury. In the infratemporal route there is a possibility of injuring that subdivision of the temporofacial branch which supplies the occipitofrontalis and corrugator supercilii, although the innervation to the orbicularis palpebrarum is only partially disturbed, as it also receives a supply from the malar and infra-orbital branches. Kocher's, the Lexer-Cushing, and the author's incision offer the surest guarantee of safety to the facial nerve. (So much stress would not be laid upon the importance of leaving the nerve intact did it not play so important a part in the etiology of keratitis, and this, after all, with the possible ultimate enucleation of the eye, is the most serious of the operative sequelæ.)

As to the selection and size of the opening in the skull, there is some difference of opinion. The lower margin of the opening should extend

down to within a reasonable distance of the ganglion, a convenient limit being the infratemporal crest. If one attempts to remove the bone as far as the foramina—a practice of the French school of surgeons—troublesome hemorrhage may arise from the pterygoid plexus of veins, and this in itself may be a serious if not a fatal complication (Krause's experience). The thickness of bone at the base of the skull is another objection to this practice. On the other hand, it is not necessary to have the upper margin of the opening extend as high as in the Hartley-Krause opening. To be precise, an opening 3 cm. in diameter, measured from the infratemporal crest, will meet all the indications. A majority of surgeons resect the zygoma, either temporarily or permanently, as a matter of convenience, though in my own experience this has not been found necessary.

Control of Hemorrhage.—At one time hemorrhage was considered the most serious obstacle to the successful operation on the ganglion and, together with infection and shock, was responsible for the greatest number of fatalities. The larger one's experience, the less consideration is given to hemorrhage as more than a troublesome feature. It is curious what a degree of variation in the amount of hemorrhage one experiences in a given series of cases. As a rule, the older the patient the freer the bleeding, but even to this statement there are marked exceptions. When spoken of in connection with operations upon the ganglion, we have in mind the bleeding which occurs when the dura is being separated from the base of the skull, and the nearer to the ganglion the freer the bleeding. It is mostly venous in origin, from the diploic veins. As a means of controlling hemorrhage, preliminary ligation of the external carotid artery has been practised, but the results scarcely justify the procedure. In one of Fowler's cases even after preliminary ligation bleeding was so abundant as to necessitate postponement of the first stage of the operation. There are but two really effective methods of hemostasis, the tampon and posture. By intelligently and judiciously placed tampons, introduced on either side of the avenue of approach, hemorrhage from this source may be controlled, and to control bleeding from the depths of the wound—that is, in the immediate neighborhood of the ganglion—there is no better way than to make direct pressure over the ganglion with the end of the retractor, which, being constantly in the wound, is always available for this purpose. The habit of filling the wound temporarily with a tampon so large as to obscure the entire field is objectionable in that it involves considerable delay. By introducing small strips of gauze directly over the bleeding points the operation may continue, as a rule, without interruption. Occasionally excessive heat may be employed to advantage by wringing the tampons out of boiling water just before they are introduced.

Posture.—Following the suggestion of Von Bergmann, the patient should be placed in the semivertical or erect posture. It serves a two-fold purpose, first in that it has a decided influence in controlling hemorrhage, and, secondly, with the stage of the operating table properly

adjusted it places the field of operation directly on a level with the eye of the operator (Fig. 451).

Ligation of the Middle Meningeal Artery.—Sufficient has already been said concerning the topography of the foramen spinosum in its relation to the ganglion, at least, to suggest the rationale of resorting to ligation as a routine procedure. However, this is a matter in which with individual operators there is some difference of opinion; thus Lexer, Krause, Kocher, and Frazier ligate the artery in every case. It requires but a moment or two to apply the ligature, and after the artery has been divided distal to the ligature, the ganglion, at least the posterior part with its sensory root, is much more easy of access.

Without a word as to the cavernous sinus, any discussion of the problem of hemorrhage would be incomplete. The sinus has been injured a number of times, but only in attempts at extracting the gan-

FIG. 451.—VERTICAL POSTURE AND SPECIAL OPERATION CHAIR AND HEAD REST FOR OPERATIONS ON THE GASSERIAN GANGLION.

glion. Though not of necessity fatal, hemorrhages from the sinus may be alarming, and in examining the records of fatal cases it will be noticed that in many instances the operation has been accompanied by such profuse bleeding as to necessitate its abandonment, at least for the time being. As a matter of fact, Lexer regarded injury to the sinus as almost unavoidable, and in 10 out of his first 14 cases because of severe bleeding the operation had to be divided into two stages. One of the strongest arguments in favor of the "sensory root," the Abbe, or Hutchinson operations is the preservation of the integrity of the sinus and adjacent nerves.

Whether or not the zygoma should be resected is a matter of little consequence. Probably the majority of operators prefer either temporary or permanent resection, although the advantages to be gained have never seemed to justify the additional time it requires.

The trigeminal nerve in many respects resembles a spinal nerve, in that it has a sensory root bearing a ganglion and a motor root. A further analogy may be drawn between the two, in that in either case once divided the sensory root will not undergo regeneration. The latter, composed only of the axones of the Gasserian neurones, leaves the posterior aspects of the ganglion and passes backward and inward through an opening in the dura mater, beneath the attachment of the tentorium cerebelli, to the posterior clinoid process. At this point, corresponding to the apex of the petrous bone, it enters the posterior fossa, traversing the latter to enter the brain-stem on the lateral aspect of the pons.

The motor root, which is distributed eventually to the muscles of mastication, the mylohyoid, and anterior belly of the digastric, after leaving the pons, follows the same course as the sensory root, and then passes behind the ganglion to become an integral part of the mandibular division. Being very much smaller than the sensory root and situated behind it, the possibility of isolating one from the other before the sensory root is divided is very remote. So that after an operation having for its object the division of the sensory root, paralysis of the muscles supplied by the motor root is an almost constant sequel; I say almost constant, because at least in one of my cases, judging from the absence of paralyis of the masseter muscle, the motor root must have been preserved.

It should be remembered, too, that the temporal muscle also receives its nerve impulses through the motor root, so that as the muscle atrophies one must expect to see a well-marked depression in the fossa above the zygoma, ordinarily filled with the temporal muscle.

The middle meningeal artery, entering the skull through the foramen spinosum, passes upward and outward along the great wing of the sphenoid, where it divides into an anterior and a posterior branch. Its course can be readily followed down to its foramen when the region is exposed in the temporal approach to the ganglion. At the anterior inferior angle of the parietal bone is a groove or, in some instances, a closed canal (Sulcus arteriosus) to accommodate the anterior branch. To avoid lacerating the vessel and so to avoid troublesome hemorrhage the opening in the skull should be made low enough to avoid this portion of the parietal bone.

One of the most important of the anatomic considerations is the relation of the facial nerve to the musculocutaneous incision. If the upper or temporofacial branch is cut, paralysis of the orbicularis palpebrarum will follow with inability to close the eye. Not only is this an unnecessary and conspicuous disfigurement, but may prove to be the determining factor in the production of an ulcerative eratitis. The latter is obviously so serious a complication that every precautionary measure must be adopted. Whatever the method of approach, therefore, the incision must be so fashioned as to leave unharmed this branch of the facial nerve. The temporofacial branch crosses the zygoma about midway between its anterior and posterior attachments, traversing

a line drawn from a point just in front of the external auditory meatus to the external angular process of the frontal bone. But before reaching this process the temporofacial division breaks up into several branches —the temporal, malar, infra-orbital—and of these each gives fibers to some portion of the orbicularis.

Of the bony processes, one should have a definite picture of the position of the infratemporal crest at the base of the skull, and of the variation in the distance between the crest and the ganglion. In most operations the opening in the skull is made to extend as far down as the infratemporal crest; the distance one must traverse from this point till one reaches the ganglion varies according to the shape of the skull. In the brachiocephalic skull the distance between those two points may be greater by from 1 to 2 centimeters than in the dolichocephalic skull.

Technic.—Many methods of exposing the Gasserian ganglion have been proposed at various times. After the suggestion of Mears, in 1884, and the operations by Rose, in 1890 and 1891, in which he employed the pterygoid route, the most noteworthy contribution was made simultaneously, but quite independently of one another, by Hartley, of New York, and Krause, of Altoona, in the year 1892. Hitherto none other than the pterygoid route had been proposed, but shortly after the Hartley-Krause contribution Horsley proposed the temporary resection of the zygoma and an approach to the ganglion by the temporosphenoidal route, an operation subsequently advocated by Poirier in 1897. From that time to the present many modifications to one or the other of the three original methods have been suggested, the most noteworthy by Keen, Tiffany, Kocher, Horsley, Hutchinson, Jr., Cushing, Abbe, and Spiller. To these must credit be given for the wonderful transformation from the somewhat hazardous undertaking of a decade or two ago to the eminently satisfactory stage of the modern technic. A description will be given of four of the most commonly used methods, but for the uninitiated in this field of surgery a word of warning should be given to any contemplating an operation upon the living subject before he has become proficient by repeated operations on the cadaver, no matter what method he chooses to employ. Even after he has familiarized himself with the steps of the operation on the cadaver he will be more or less embarrassed at his first experience on the living subject by the more or less continuous oozing—a troublesome feature —to which his work on the cadaver will not accustom him. Finally, in his selection of a method he must choose that which in his own hands he finds the most effective; that is, the one which he executes with the least risk not only to the life of the patient, but with the minimum damage to the structures in the operative territory.

Discussion of the Various Operative Procedures.—For reasons already given, the "sensory root" operation is believed to be the operation of choice. Even to the impartial observer there can be no doubt that it is easier to avulse the root than to remove all or a portion of the ganglion. As Bryant says, "Should the outcome show that failure of regeneration

of the divided or resected nerve prevents the return of the affliction, *then, indeed, will the technic be simplified and the dangers and sequels correspondingly lessened.*"

The Two-stage Operation.—This should be regarded only as a resort of necessity and not of choice, and it will be necessary only in exceptional instances. In my own series of 28 cases it was resorted to only twice, and in one the source of hemorrhage was a large vascular tumor at the base of the skull with secondary involvement of the ganglion. The objections to the two-stage operation are self-evident; first, there is the risk and annoyance of a second anesthetization; second, there is the risk of infection, since the tampon introduced into the wound to control hemorrhage serves as an avenue of infection; and third, what is of more serious moment, the continued pressure of the tampon on the cortex has caused such pressure phenomena as aphasia and even hemiplegia. On an average, the operation should be completed in from one to two hours; with the patient carefully anesthetized and properly protected against exposure, there is no reason why the operation should not be completed in one stage. There may be exceptional instances in which, because of persistent bleeding or the intolerance of the patient to the operative procedure, it may be more prudent to postpone the final stage of the operation for a few days.

The Hartley-Krause Method.—A horseshoe-shaped incision is made down to the bone, beginning just behind the external angular process of the frontal bone and terminating in front of the tragus. The superior margin of the flap corresponds to the supratemporal ridge and the base of the flap to the zygoma. The corresponding underlying bone is divided along the lines of the musculocutaneous incision, and the osteoplastic flap thus formed is reflected. In this procedure the middle meningeal artery or its branches may be torn and hemorrhage should be controlled by ligation. The zygoma is not resected. The ganglion and its divisions are then exposed by separating the dura and cautiously raising the brain from the middle fossa. The second and third divisions are exposed and traced backward to the ganglion. After the latter has been thoroughly isolated, it is seized with hemostatic forceps, the second and third divisions divided with scissors at their point of entrance into the foramina, then, by rotating the forceps, the remainder of the ganglion, together with the motor root, is torn from its bed.

The Lexer-Cushing Method of Exposure.—The essential feature of this method is the low position of the incision as compared with the high Hartley-Krause incision. The latter is described as the temporal and the former as the infratemporal root. The anterior limb of the Lexer incision terminates just behind the frontal process of the malar bone. The anterior limb of the Cushing incision is still shorter. The posterior end of the incision of both terminates a finger's breadth in front of the ear over the root of the zygoma. Lexer reflects the zygoma temporarily and Cushing removes it. After separating the musculocutaneous flap and the periosteum from the under surface of the great

ring of the sphenoid as far as the infratemporal crest, an opening is made in the skull and enlarged forward, backward, and downward, almost as far as the foramen ovale. The upper margin of the opening should be below the sulcus arteriosus of the anterior inferior angle of the parietal bone. Lexer ligates the middle meningeal artery in all cases, Cushing does not. Both recommend in all cases the removal of the ganglion *in toto.*

Horsley's Method.—His method of exposure corresponds very closely with that just above described. Horsley, however, concludes the operation with the complete extraction of the ganglion in the following way: "The anterior and superior borders of the ganglion, having been divided with a sector and raised by pulling up from its bed, it is then separated by dividing the inferior division, then the middle division, and, finally, by detachment of the superior divisions of the ganglion. The ganglion is then drawn up until it is found that the sensory and motor roots have become detached from the pons and is extracted in its full length."

Kocher's Method.—This differs radically from all others in that the incision is made with the convexity downward, beginning about 1 cm. behind the frontal process of the malar bone and extending obliquely downward to just below the root of the zygoma. It is carried from this point at right angles upward, just in front of the ear. This incision is designed especially to avoid injuring the upper branch of the facial nerve. The temporal arteries are ligated and the temporal fascia and periosteum separated from the upper end of the zygoma; the latter is temporarily resected. The opening of the skull extends down almost as far as the foramina ovale and rotundum and upward for a distance of 3 cm., separating the dura from the base of the skull; the middle meningeal artery is ligated and the maxillary division of the nerve exposed. At this point the dura propria is divided and dissected backward sufficiently to expose the posterior aspect of the ganglion. The sensory root is picked up on a hook, grasped with forceps, and slowly avulsed. Kocher has not seen a case of recurrence after this plan of operation.

Hutchinson's Method.—An oval musculocutaneous flap is reflected, having its base at the zygoma and its upper end 1½ inches above, its posterior border running toward the condyle of the lower jaw. Upon reflecting the flap several branches of the temporal artery are secured with forceps, and an opening in the skull made with a trephine midway between the external auditory meatus and the external angular process of the frontal bone. The opening is enlarged with Hoffman's forceps as far as the infratemporal crest, and after detaching the dura from the floor of the middle fossa the inferior and superior maxillary divisions are thoroughly exposed. The dural sheath of the ganglion is detached in an upward and backward direction until the greater portion of the ganglion has been exposed; with a narrow-bladed knife or tenotome the inferior and superior maxillary divisions are cut cleanly across, just above the foramina, the ganglion grasped with toothed forceps,

and the outer two-thirds removed. That portion in relation to the ophthalmic division and the ophthalmic division itself are left intact. Hutchinson believes in some cases it is impossible to expose the ganglia sufficiently without tying and dividing the middle meningeal artery.

FIG. 452. — BLUNT HOOK EMPLOYED IN THE SENSORY ROOT OPERATION.

Abbe Method.—In 1903 Abbe suggested a simplification of the more radical procedures, which consisted in dividing the inferior and superior maxillary divisions, followed by the interposition of rubber tissue or a rubber disk to prevent regeneration of the nerve. The ganglion is left intact. He has been able to obtain sufficient exposure of the structures through a vertical incision, and in this respect the technic differs from the others hitherto described.

The Spiller-Frazier Method (*Division of the Sensory Root by the Auriculotemporal Route*).—The essential features of this operation is the division or avulsion of the sensory root exclusively without interfering with the ganglion itself. The approach to the ganglion is made through an opening somewhat posterior to that employed by other surgeons. The center of this opening is about on a line with the point at which the sensory root passes into the ganglion. Inasmuch as this method does not necessitate exposure of the anterior portion of the ganglion, including its first and second divisions, this method of approach is preferred. Under nitrous oxid ether anesthesia, preceded by the administration of a hypodermic injection of morphin (grain $\frac{1}{6}$) and atropin sulphate (grain $\frac{1}{150}$), with the patient in the vertical posture, a horseshoe-shaped incision is made, beginning about the middle of the zygoma and terminating behind and a little below the helix of the ear. The musculocutaneous flap, purposely made a little larger than the opening in the skull, is reflected, the skull opened, and the opening, with a diameter not exceeding 3 cm., enlarged as far as the infratemporal crest (Fig. 454). The dura is separated from the base of the skull with a blunt instrument, such as the handle of a scalpel, as far as the foramen spinosum, where the middle meningeal artery is ligated and divided distal to the ligature (Fig. 455). The dura propria is incised directly over the mandibular division and dissected from the superior surface of the ganglion backward and inward until the sensory root is exposed. If the motor root can be recognized, it should be isolated. The sensory root is then picked up with a blunt hook, grasped with forceps, and either divided or avulsed (Fig. 456). Hemorrhage is controlled throughout the course of the

operation by strips of gauze not more than 1 cm. in width, introduced to either side of the avenue of approach in such a way as not to interfere with the continuation of the operation. As soon as the sensory root has been divided the anesthetic is discontinued, inasmuch as all the structures in the field of operation have been rendered anesthetic and

FIG. 453.—SPECIAL LIGATURE CARRIER FOR LIGATION OF THE MIDDLE MENINGEAL ARTERY.

the patient will experience no pain in the subsequent steps of the operation. When the reflexes have returned, the conjunctival reflexes should be tested in order to assure the operator that no fibers of the sensory root remain undivided. The musculocutaneous flap is closed with tier sutures and a small narrow strip of rubber tissue introduced

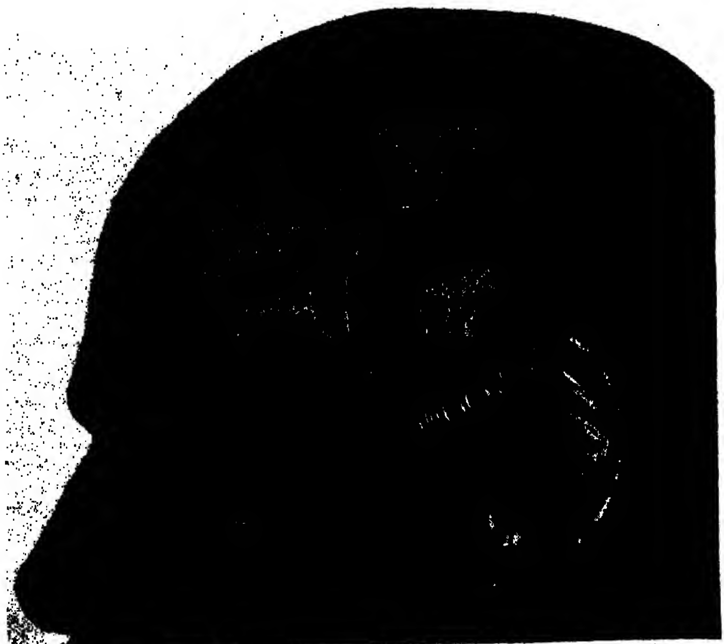

FIG. 454.—SHOWING THE RELATIVE POSITION AND SIZE OF MUSCULOCUTANEOUS FLAP, THE BASE OF WHICH CORRESPONDS TO THE LEVEL OF THE ZYGOMA.

in the posterior angle of the wound. It is almost always necessary to provide for the escape of blood, inasmuch as only exceptionally will the field be entirely dry when the operation is concluded. The rubber tissue is removed within twenty-four or forty-eight hours.

Division of the sensory root was first practised by Frazier in 1901, and since that time has been used almost exclusively. There has been

no evidence of regeneration of the sensory root. The advantages claimed for this operation over extirpation of the ganglion are: first, that it is attended with less hemorrhage because the ganglion is not raised from its bed. In extirpation of the ganglion the most troublesome bleeding is experienced at this stage of the operation; second, it does not expose to injury the adjacent structures—viz., the cavernous sinus and the three cranial nerves; third, it is possible, though very rarely, to preserve the motor root and thereby avoid disturbance of the functions of the muscles of mastication; and. finally, there is less likelihood of ulceration of the cornea.

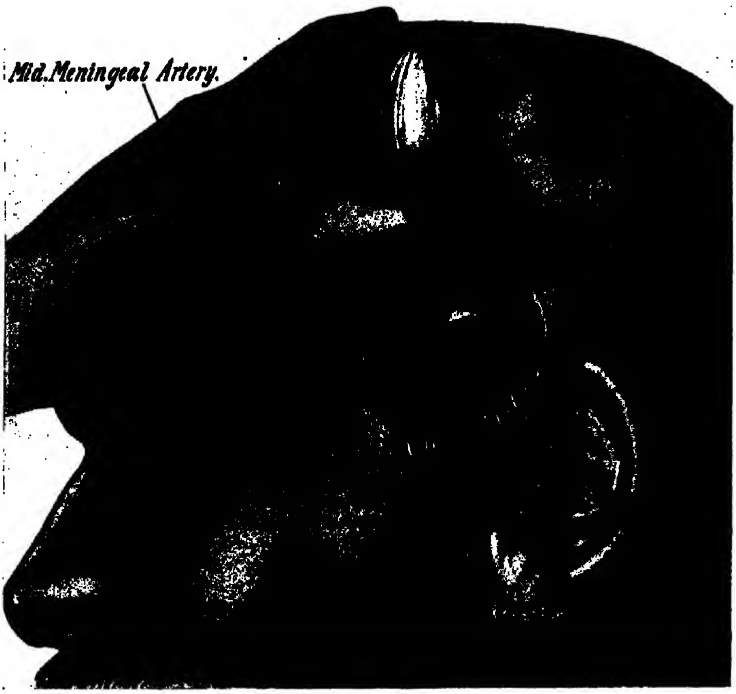

FIG. 455.—RELATION OF STRUCTURES IN THE MIDDLE CEREBRAL FOSSA IN THE APPROACH TO THE GANGLION.

The brain has been elevated with a spoon as retractor as far as the foramen spinosum. A ligature is being passed around the middle meningeal artery.

The patient, directly or indirectly through his physician consulting a surgeon as to whether or not he should submit to an intracranial operation for the relief of obstinate tic douloureux, usually wants to be informed as to the following points: first, the immediate risk; second, the possibility of recurrence; and third, the possible unfavorable complications. Not all patients with "tic" will consider the matter in this deliberate philosophic fashion; many are so desperate that they insist at any risk upon having the operation performed without delay. Suicide with them is often the only alternative proposition. But to those who are in doubt as to the course to pursue, it is only right that

they should be provided with as many data as they may need in order to enable them to draw an intelligent conclusion.

Mortality.—The chances of recovery will depend somewhat upon the experience of the surgeon, a factor more true of this than of most other operative procedures. As Allen Starr once said, he would recommend an intracranial operation providing he could choose the surgeon. In a series of 230 cases which I have collected from the clinics of Horsley, Lexer, Döllinger, Cushing, and Frazier the mortality was 3.7 per cent. This represents the risk of the operation to-day in competent hands. But the idea is still prevalent among physicians that the death-rate is

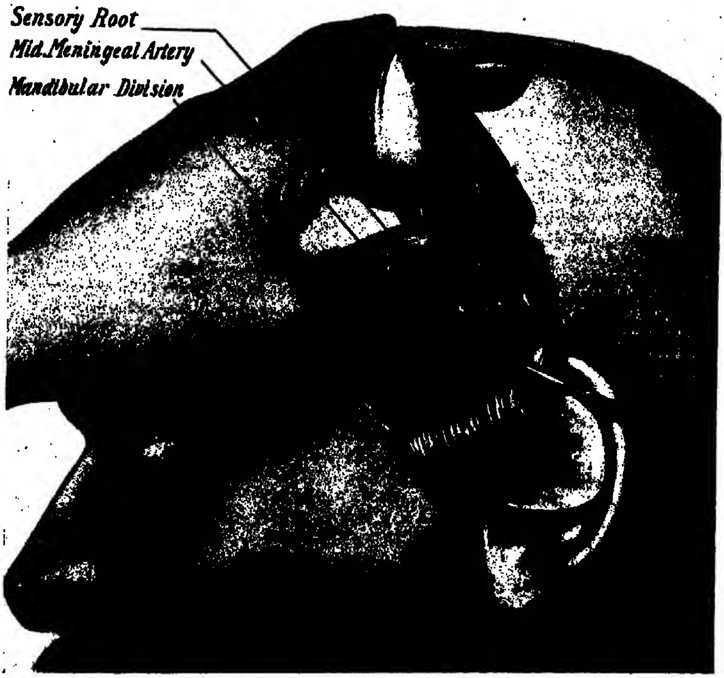

Fig. 456.—Final Stage in the "Sensory Root" Operation.
The mandibular division and the posterior aspect of the ganglion have been exposed and a hook passed around the sensory root preliminary to avulsion.

very much higher, and the table of Tiffany's, with a mortality of 22 per cent. in a collected series of 108 cases, still finds its way into some modern writings. As an example of an individual experience, in my own series of 28 cases there was but 1 death (3.6 per cent.), and this occurred in an aged patient and not until the tenth day after operation. While it is more than probable that in the next ten years the mortality will be still further lowered, these figures represent the risk of the intracranial operation at the present day. Taking into consideration the age and wretched condition of the patients at the time of operation, the risks of this operation compare favorably with that of many other major procedures in patients as old and debilitated.

The most common causes of death in the past have been shock and hemorrhage, cerebral complications, and infection. In this day of asepsis the latter should be almost eliminated as a factor, especially if the practice of dividing the operation into two stages be abolished. As for shock, if the anesthetization is entrusted to competent hands and proper methods are adopted to control hemorrhage, there should be none. Hemorrhage, prolonged exposure, and careless anesthetization are the only conditions which could be held accountable for an operative death; that is, a death within the first twenty-four or forty-eight hours after operation. In a series of 16 fatal cases selected by Hutchinson

FIG. 457.—PHOTOGRAPH TAKEN DURING AN OPERATION FOR AVULSION OF THE SENSORY ROOT; NOTHING BUT THE FIELD OF OPERATION IS EXPOSED.
Note the size of the opening, the use of the spoon as a brain elevator, and the small tampon used for the control of hemorrhage.

the largest number died as a result of hemorrhage or shock, most of these within the first twenty-four hours; the second largest number from infection, seven days to three months after operation, 2 died with hemiplegia, and 1 death was attributed to a fatty heart.

Recurrence.—There is no doubt but that in a certain percentage of cases there have been genuine recurrences after operations having for their object the extirpation of the ganglion. There is also not the least doubt in my own mind that a number of these, particularly in cases reported a decade or so ago, were attributable to the incomplete way in which the ganglion was removed. In considering recurrence, however,

we must, of course, exclude all cases in which the pain returns upon the opposite side, but fortunately this seldom occurs, as neuralgia of the fifth nerve is rarely bilateral except in diabetes (Gowers).

Lexer tabulated a series of 201 cases, and found 93 per cent. free from recurrence. It is difficult to account for actual recurrence when the ganglion has been removed *in toto;* nevertheless, there seem to be a few authentic cases, but not as many as are represented in Lexer's figures. There are a number of authors, including Van Gehuchten and Kocher, who feel convinced that the possibilities of recurrence after the division or avulsion of the sensory root, or, as Van Gehuchten has styled it, "physiologic extirpation of the ganglion is practically nil." I have yet to see a case of recurrence in which I was sure all the fibers of the root had been removed, and Kocher has had a similar experience.

Cerebral Complications.—Looking over the more recent contributions to the literature of trifacial neuralgia, I have been impressed with the absence of any cerebral conditions complicating operations upon the ganglion. The earlier literature of the subject does contain, however, references to such complications as temporary somnolence, restlessness, vertigo, cephalalgia, and aphasia. In my own series of 28 cases there have been no complications such as these; in Krause's series of 27 cases, reported before the Thirtieth Congress of the Deutsche Gesellschaft für Chirurgie in 1901, he had noted at least one instance of each of the above disturbances. Keen, Poppert, and others have reported cases in which the patient became hemiplegic on the side opposite that of the operation, but in one instance on the side of the operation. Lexer records an instance of transitory aphasia and somnolence, and Collins refers to an instance in which the patient's memory was said to be permanently affected. There is no doubt that in the majority of cases these disturbances are due to direct pressure upon the brain by the retractor, or in certain instances by the introduction of large tampons of gauze. The latter is a vicious habit and should not be countenanced, and, knowing the effect of undue pressure upon the cortex, every precaution should be exercised to protect it against such needless trauma. One should not under any circumstances make pressure upon the motor cortex, either directly by means of the retractor on the side of the operation or indirectly by pressing the cortex on the opposite side against the skull. In order to secure an adequate exposure it is necessary to elevate the brain slightly, not more than ½ inch above the base of the skull. This will open a vista large enough for all practical purposes, and if natural illumination is not sufficient to light up the depths of the wound, the operator may use an incandescent head lamp. The fact that the frequency of the cerebral complication has diminished so materially in the past five or six years must be attributed to the fact that the opening in the skull is not as large as it once was, nor extends quite so high, so that the motor cortex is not uncovered and unprotected, and, therefore, is not exposed to danger by pressure.

An interesting phenomenon occurring in my experience, interesting perhaps only because unique, was a transitory hypoglossal palsy, first

noticed two days after the operation. The patient protruded the tongue to the affected side, so that there was evidently some disturbance, peripheral or central, of the innervation of the right side of the tongue. That the hypoglossal nerve should have been injured during the operation is, of course, out of the question, or that pressure on the cortex could have involved the center presiding over the movements of the tongue to the exclusion of any other seems equally inconceivable. The paralysis, however, was only transitory in character, and had practically disappeared when the patient was discharged from the hospital.

Facial Paralysis.—Injury to the facial nerve in the performance of any operation is a deplorable accident. In operations upon the Gasserian ganglion it has a special significance. The inabilit of the patient to close the eye completely, and thus to protect the insensitive cornea by keeping it warm and moist, at least predisposes toward corneal complications, although, of course, there are other influences, trophic in nature, which no doubt play a considerable part. It is the paralysis of the muscles supplied by the upper branch of the facial nerve, and particularly the orbicularis palpebrarum, that is most frequently seen, although in some instances the paralysis has involved the entire distribution of the nerve. In the latter instance the paralysis may be due to pressure on the cortical center itself, or in some instances, I believe, to the direct pressure upon the nerve trunk caused by the blade of the retractor in making downward traction upon the musculocutaneous flap. Porter, in describing a case of complete facial palsy, suggested that the paralysis may have been due to trauma resulting from traction upon the chorda tympani. Sufficient has already been said in the discussion of the anatomic considerations of various operative procedures as to the importance of so designing the incision as to avoid severing the upper branch of the facial nerve.

Cutaneous Anesthesia.—When the connection between the peripheral distribution and the medullary center has been cut off, either by avulsion of the root or by extirpation of the ganglion, it is interesting to note the wide variation in the area of cutaneous anesthesia. The sensory portion of the trigeminus supplies common sensation to the front part of the head, the face, a portion of the external ear, the eye, the nose, palate, nasopharynx, and part of the mouth and tongue. The diagrammatic representations of the trigeminal distribution represent this area by a line drawn from the vertex of the skull to the chin, thence along the lower border of the jaw to its angle, thence upward, including a part of the ear and temporal region, until it reaches the median line. After extirpation of the ganglion or division of the sensory root the area so outlined is by no means constant; while the anesthesia usually extends to the median line, it often stops 2 or 3 cm. short of the lower border of the jaw and does not always include the ear. Furthermore, it has been noticed that even though immediately after operation the area of anesthesia is represented by what might be called the maximum distribution, in course of time sensation may be recovered in what might be called the doubtful zone. The explanation of these phenomena is to be found in

the presence in this zone of fibers of the posterior roots of the cervical nerves. In a number of dissections of the cervical and trigeminal nerves Zander traced them to their smallest filaments, and found that the distribution of the cervical nerves, on the one hand, and the trigeminal, on the other, overlapped one another over a considerable area. He was the first to call our attention to the fact that the cervical nerves innervate more of the cutaneous surface of the face and head than is usually depicted in diagrams, and also that the area of distribution of the nerves on one side of the head may extend beyond the median line. In comparing the diagrammatic representation of Zander's sections (Fig. 458) with the record of an individual case made at the time of the operation several years later it will be seen how the area in which the cervical and cranial nerves overlap one another corresponds to the area in which there has been partial return of sensation. The return of sensation must be accounted for by the presence of the cervical nerves rather than to any reëstablishment of the trigeminal tract, otherwise we would find also some recurrence of pain, a phenomenon which has not been observed.

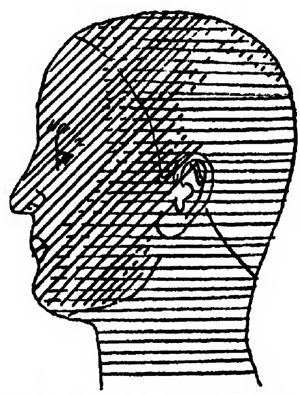

FIG. 458.—ZANDER DIAGRAM SHOWING OVERLAPPING OF THE DISTRIBUTION OF THE CRANIAL AND SPINAL NERVES.

Ocular Complications.—These may be both motor and trophic.

(*a*) **Motor Disturbances.**—The third, fourth, and sixth nerves, because of their proximity to the inner aspect of the ganglion, are always exposed to injury in attempts at extirpation, and because the sixth, or abducens, lies nearest the ganglion it is more frequently damaged than the others. With a view toward protecting these nerves from injury, Hutchinson and Abbe recommended only partial extirpation of the ganglion, leaving intact its inner portion, together with the ophthalmic division.

(*b*) **Trophic Disturbances.**—Apart from the cerebral complications, the most serious that can follow operations upon the ganglion or its sensory root is a keratitis. While this is favored by paralysis of the upper branch of the facial nerve with inability of the patient to close the eye, the most important factor probably is the disturbance of the trophic influences, because keratitis may develop even when there has been no facial paralysis. Spiller believes that there may be certain nerve-cell bodies in the ganglion itself which exert some trophic influence upon the cornea, and if they are left intact ulceration of the cornea is less likely to occur. Theoretically, therefore, there should be fewer cases of corneal complications when the operative intervention is limited to the sensory root and no attempt is made to remove the ganglion. The proposition of Hutchinson and Abbe to leave the ophthalmic division and a portion of the ganglion intact is deserving of very serious consideration because of the protection it ensures against the development of keratitis. Under

all circumstances, no matter what the operation, certain precautionary measures should be adopted. The eye should be protected by a suitable shield, such, for example, as may be offered by an automobile goggle (Fig. 459), and the condition of the eye should be carefully observed

FIG. 459.—PHOTOGRAPH OF PATIENT ONE WEEK AFTER OPERATION, SHOWING USE OF AUTOMOBILE GOGGLE FOR PROTECTION OF EYE AND POSITION OF FLAP WITHIN THE HAIR LINE. (Author's case.)

for several weeks or even months after the operation, inasmuch as corneal ulceration may not develop for a considerable time. While the majority develop within the first two or three weeks, some, as in Hutchinson's case, do not develop until some months after the patient has been discharged.

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Tumors of the Gasserian Ganglion.—Whether primary or secondary, tumors of the Gasserian ganglion are not common. The writings of Spiller, Marchand, Hofmeister and Meyer, and Raffaello Giani fully cover the entire subject and include all the cases hitherto reported. A discussion of the lesions which might involve the trigeminal tract secondarily would take us too far afield, as they would include tumors of the pons or cerebellopontile space infiltrating or pressing upon the sensory root, and tumors taking their origin from the structures of the middle fossa other than the ganglion.

Genuine secondary tumors, in the sense of their being metastatic deposits, are quite uncommon. Marchand refers to one case of primary carcinoma of the stomach and to another of melanotic alveolar sarcoma of the forearm with metastatic deposits in the ganglion.

There are about 14 cases of primary tumors of the Gasserian ganglion on record: viz., 1, Günsburg; 2, Blessig; 3, Hansch; 4, Petrina-Klebs; 5, Goodhart; 6, Krogius; 7, Prince; 8, Marchand; 9, Hegelstamm; 10, Dercum, Keen, and Spiller; 11, Hofmeister and Meyer; 12, Spiller. Most of them were uncovered for the first time at autopsy. In only 4 cases (1, Krogius; 2, Dercum, Keen, and Spiller; 3, Spiller-Frazier; 4, Hofmeister-Meyer) was an operation undertaken with the definite purpose of removing the tumor.

In the majority of instances the tumors are of a malignant type, and have been designated variously as sarcoma, fibrosarcoma, endothelioma, and neurofibroma. In spite of the apparent variety of tumors, Marchand regards the histologic structure of all as quite uniform. He believes further that they arise in the undifferentiated *anlage* of the ganglion, and may, therefore, be regarded as neurozytomata. Whatever the nomenclature, these tumors are of the infiltrating type, eventually involve adjacent structures, *e. g.*, the neighboring nerves, internal carotid artery, and cavernous sinus; they may attain considerable size, as in the case of Günsburg, in which the tumor was said to be the size of a goose egg, may extend upward into the temporal lobe, backward into the posterior fossa, or forward into the orbit.

The recognition of the seat and nature of the lesion is not always a matter of great difficulty. Occasionally syphilitic meningitis has been mistaken for tumors. In the earliest stages the pain may closely resemble that of idiopathic epileptiform neuralgia, but later on added to the neuralgia, which may be quite as intense as in that of the idiopathic type, there will be disturbances of sensation (anesthesia, hyperthesia, hypesthesia), weakness of the muscles of mastication; disturbances of structures innervated by the third, fourth, and sixth nerves, and evidences of pressure upon the cavernous sinus or internal carotid artery. In addition to these special localizing phenomena, there is the triad of symptoms common to all brain tumors—headache, nausea and papillo-edema—and in about 25 per cent. of cases metastasis to the cervical lymph-nodes; the latter is, of course, a late symptom and consequently of little significance, except in so far as it may indicate an unfavorable prognosis. As a matter of fact, the prognosis is always grave; because of its situation and malignant nature the tumor may be said to belong to the inoperable group.

The treatment, therefore, of tumors of the Gasserian ganglion in the majority of cases will be palliative. It is possible to conceive of a case in which the tumor was still within the structure of the ganglion and, therefore, in the operable stage, but as yet this has not occurred. No one should question the propriety of palliative operation in these cases; not only should the sensory root be divided or avulsed for the relief of pain, but a temporal decompression should be practised at the

same time in order to relieve the intracranial tension. Thus, there is in the palliative operation a twofold purpose. In my series of 28 cases there was one who was believed to have a tumor of the brain involving the ganglion. The patient suffered intensely and his condition was pitiable. Although the tumor was believed to be inoperable, an operation was undertaken with the understanding on the part of the patient that it was solely for the purpose of relieving his neuralgia and would have no effect upon the fatal tendencies of the tumor. A portion of the ganglion was removed and decompression established in the temporal region, no attempt being made to remove the tumor. The patient died several months later, but in the interim he was entirely free from neuralgia.

The first operation, however, was performed by Krogius in 1895; he found an endothelioma about the size of a pigeon's egg, only a portion of which he could remove, and the child died of meninigtis on the thirteenth day. In Keen's case two operations were performed, one extradural, the other intradural; a large tumor was removed, and the patient recovered from both operations. One of the interesting features of this case and the case of Hofmeister and Meyer was the persistence of pain after the ganglion had been removed. Although the possibility of the sensory impulses being transmitted by the seventh nerve has been considered, it is more probable that the persistence of pain was due to infiltration of the sensory root.

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II. THE AUDITORY NERVE (N. ACUSTICUS).

Anatomic Considerations.—The anatomic landmarks which guide one in operations upon the auditory nerve are familiar to every surgeon who has explored the posterior fossa for other purposes. After leaving the surface of the brain-stem at the posterior border of the pons, where it is adherent to the middle cerebellar peduncle, this nerve passes across to the internal auditory meatus, and enters the internal auditory canal to divide into its two main branches, the vestibular and cochlear nerves. In its passage from the cerebellar peduncle to the entrance of the auditory canal the auditory nerve is closely associated with the motor and sensory roots of the facial nerve; the latter lies to the inner side in a groove on the mesial surface of the auditory nerve. For this reason in the approach along the pars petrosa the view of the facial nerve is entirely obstructed. The facial nerve is much smaller, approximately one-third the size of the auditory nerve, and is practically surrounded by it. To separate one from the other is not always an easy matter, although

this may be facilitated somewhat by displacing the cerebellar hemisphere backward. This puts both nerve-trunks on the stretch, and sometimes separates one nerve from the other sufficiently to enable one easily to differentiate them. A little farther beyond the eighth nerve, as it enters the internal auditory meatus, may be seen the root of the trigeminus. In operations for the exposure of the auditory nerve one usually sees in the operative field the nerves which make their exit through the jugular foramen (foramen posterius magnum), namely, the ninth, tenth, and eleventh cranial nerves. The jugular foramen is only about 1 cm. distant from the internal auditory meatus and almost directly posterior to it. The proximity of this foramen is mentioned because of

FIG. 460.—HORIZONTAL SECTION OF THE HEAD CUT ON A LEVEL WITH THE EXTERNAL AUDITORY MEATUS.

On the left side may be seen the auditory nerve as it enters the internal auditory meatus. The illustration is particularly valuable as showing that the shortest and most practicable route to the cerebellopontile angle is from the lateral aspect following the direction of the petrous bone.

the possibility of exerting undue trauma upon the nerves which pass through it. Of these three, the ninth or glossopharyngeal, seems to be the most frequently affected in exploratory operations. At least I have not infrequently noticed afterward that the patient complained of difficulty in swallowing when there were no symptoms pointing to disturbance either of the vagus or the hypoglossal nerves. In making the opening in the skull preliminary to exposure of the auditory nerve one must bear in mind the relative position of the lateral sinus (sinus transversus) and the longitudinal sinus, the one above, the other to the inner side of a unilateral opening. Attention should also be called to the more or less numerous emissary veins, particularly in the region of the external occipital protuberance and in the neighborhood of the mastoid

process (Fig. 460). The largest of these, however, is the mastoid emissary, which establishes a communication between the lateral sinus and the posterior auricular or with an occipital vein. This passes

FIG. 461.—IN THIS PHOTOGRAPH OF A PORTION OF THE BASE OF THE SKULL BELOW THE SUPERIOR CURVED LINE WILL BE SEEN NUMEROUS FORAMINA FOR THE PASSAGE OF EMISSARY VEINS. Note the size and number of these. Their presence accounts for the profuse hemorrhage one frequently encounters in operations necessitating exposure of this region.

obliquely through the skull just above the mastoid process, and will invariably be opened in removing the bone from this region. Hemorrhage may be controlled either by ligation or by blocking the fora-

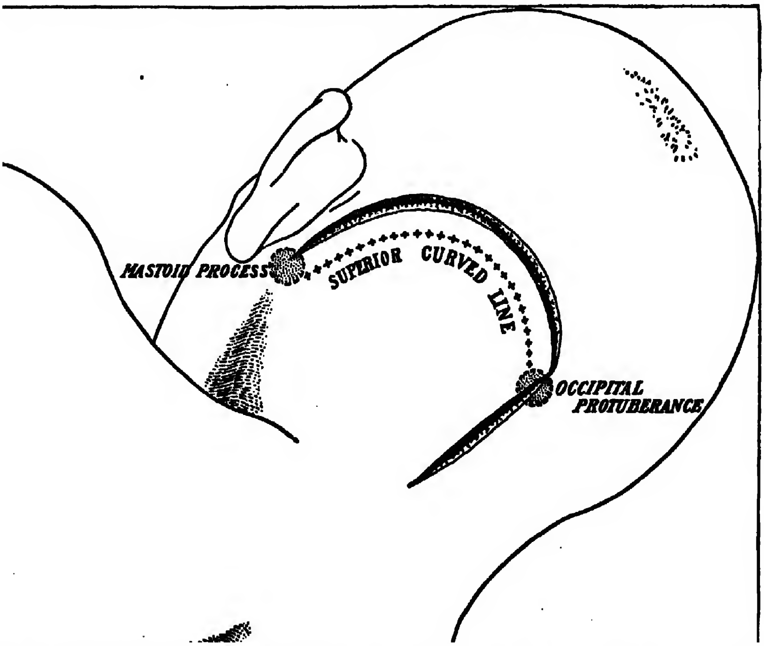

FIG. 462.—SCHEMATIC PRESENTATION OF INCISION FOR A UNILATERAL SUBOCCIPITAL CRANIECTOMY. The cutaneous incision should be ½ inch above the superior curved line; incision in the muscular structures just below the superior curved line.

men with Horsley's wax. In laying bare the cerebellar hemisphere by removing the overlying bone the proximity of the foramen magnum and the medulla oblongata should not be lost sight of.

The Technic of Operations for Exposure of the Auditory Nerve.—There are many points in the technic which might admit of discussion. The most important of these, perhaps, is the question whether it is necessary or advisable to make a bilateral opening—*i. e.*, to uncover both cerebellar hemispheres. In my opinion, a unilateral opening should suffice in most cases, however, and inasmuch as more time is consumed and more blood lost in making a bilateral opening, the latter should not be practised as a routine procedure. It should be reserved for those cases in which, because of the presence of a tumor, the tension within the fossa is so great as to interfere with the necessary displacement of the hemisphere. The incision for the unilateral opening begins at the tip of the mastoid process, running parallel to and 1 to 2 cm. above the superior curved line to the external occipital protuberance,

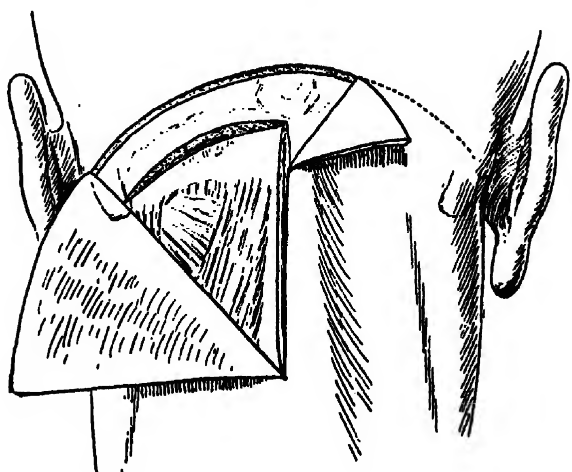

FIG. 463.—DIAGRAMMATIC PRESENTATION OF THE POSITION OF THE INCISION IN THE SCALP RELATIVE TO THE INCISION IN THE MUSCULAR STRUCTURES (SUBOCCIPITAL CRANIECTOMY.) Note that the incision in the muscular structure is a centimeter or two distant from the incision in the scalp.

and thence downward following the median line. This incision should include only the structures of the scalp (Fig. 463); 2 cm. below and parallel to the incision in the scalp, the fascia and muscles are divided down to the bone. After reflecting the musculocutaneous flap thus formed the bone overlying the hemisphere is then removed from the mastoid process at least as far as the median line, and from ½ inch above the lateral sinus down as far as the foramen magnum (Fig. 464). An opening of this size will enable one to displace the hemisphere sufficiently to expose the auditory nerve in the majority of instances. If not, it is always possible to remove the bone overlying the hemisphere on the opposite side. There are some surgeons, notably Krause and Borchardt, who still prefer the osteoplastic method. In this particular region the technical difficulties of osteoplastic resection are not inconsiderable, and the cerebellar tissue is so well protected by the thick

layer of muscles and the dense fascia as to make it quite unnecessary to replace the bone.

During these preliminary steps of the operation there may be more or less free hemorrhage from the musculocutaneous flap, but this is readily controlled. Hemorrhage from the emissary veins may in some instances be alarmingly profuse, especially in those cases in which the veins are unusually abundant and exceptionally large. The dural flap is now reflected, and with a suitable retractor the cerebellar hemisphere

FIG. 464.—SCHEMATIC PRESENTATION OF STRUCTURES AFTER REFLECTION OF MUSCULOCUTANEOUS FLAP AND REMOVAL OF BONE. (See Figs. 462 and 463.)

is displaced somewhat backward until the auditory nerve is brought into view. This is perhaps the most important step of the operation, inasmuch as serious consequences may result in the attempt to displace the hemisphere by making too much pressure upon the medulla. One might infer from certain illustrations that the cerebellar hemisphere may be dislocated to an unlimited degree (Fig. 467), but this is far from the truth. In fact, one should always be content with the minimum degree of exposure. The pressure should always be made directly backward, and not inward, so as to avoid direct pressure on the

medulla. In most instances it will not be necessary to displace the cerebellar hemisphere more than 1 cm. from the posterior surface of the petrous bone. Especial care must be taken to avoid lacerating the cerebellar tissue, either by undue pressure with the retractor or by allowing it to impinge against the irregular margin of the bony opening. In order to protect the hemisphere against such laceration,

FIG. 465.—SHOWING THE POSITION AND RELATION OF STRUCTURES AS VIEWED FROM THE LATERAL ASPECT.

The dural flap has been reflected and the cerebellar hemisphere displaced only enough to expose the auditory and facial nerves. Note the proximity of these structures to the ninth, tenth, and eleventh nerves traversing the jugular foramen. The auditory nerve has been separated from the facial by a blunt hook. Otherwise the facial nerve would be entirely hidden from view. (Original.)

Ballance suggested the use of flat marine sponges, a suggestion which I have found most serviceable.

Separating the hemisphere from the petrous bone may occasion quite free bleeding, but it is usually venous and easily controlled by introducing a small wick of gauze. Quite a constant source of bleeding in this stage of the operation is the rupture of a small vein which passes across from the cerebellum to enter the occipital sinus.

The posture of the patient is one that demands no little consideration. The field of operation is much more difficult of access than in

FIG. 466.—SHOWING THE POSITION AND DIRECTION OF THE INCISION FOR EXPOSURE OF THE CEREBELLOPONTILE ANGLE (UNILATERAL SUBOCCIPITAL CRANIECTOMY).

operations upon the middle or anterior fossa. No matter what the posture of the patient, the head must be flexed; Krause places the

FIG. 467.—THIS ILLUSTRATION, TAKEN FROM A RECENT CONTRIBUTION OF KRAUSE'S, IS REPRODUCED BECAUSE IT GIVES AN ERRONEOUS IMPRESSION OF THE DEGREE OF DISPLACEMENT OF THE CEREBELLUM WHICH IS EITHER PRACTICABLE OR JUSTIFIABLE IN EXPOSURE OF TUMORS OF THE CEREBELLO-PONTILE ANGLE. (Compare with Fig. 465.)

patient in the sitting posture with the head bent forward; Cushing places the patient in the prone (belly-down) position. For various reasons I prefer to operate with the patient lying on his side, with the

head of the table well elevated to control venous bleeding (Fig. 468). In this position respiration is not interfered with, a matter of considerable import when operating upon patients with cerebellar tumors, and as in all cases the auditory nerve should be approached from the lateral rather than the posterior aspect, the operator, without stooping or bending, is afforded a direct view into the depths of the wound. To my mind there is no question as to the superior advantages of the lateral approach; it offers the shortest route from the margin of the opening to the cerebello-pontile angle and permits of the cerebellar hemisphere being displaced backward rather than inward. By the latter method the pons and medulla are exposed indirectly to trauma.

FIG. 468.—THE AUTHOR'S TABLE, ESPECIALLY CONSTRUCTED FOR SUBTENTORIAL OPERATIONS. The lateral position of the patient is maintained by special device attached to the deltoid region By moderate flexion of the head the field of operation is rendered most accessible.

As soon as the nerve is reached the manipulations differ according to the lesions to be dealt with. For tinnitus or vertigo it will be necessary only to divide the auditory nerve. The nerve is readily recognized, not only by its glistening snow-white appearance, but by its position relative to the internal auditory meatus and the nerves entering the jugular foramen, from which it is separated about a centimeter. The nerve lies about 4 or 5 centimeters from the anterior margin of the wound. Before dividing the auditory, the facial nerve must be isolated. This may be a matter of considerable or of little difficulty, but is always a matter of great importance, as a residual facial paralysis might be regarded by the patient as an unpardonable offence. As the auditory nerve almost surrounds the facial nerve, the ease with which a few fibers of the auditory nerve may be left behind in separating the two

must be borne in mind. Once the nerve has been isolated it should be grasped with forceps and avulsed. The success or failure of the operation will depend, of course, upon whether or not any strands of the nerve are left undivided.

When it comes to the removal of tumors from the auditory nerve—acoustic neurofibromata—we have a more difficult problem. Because of the size of the tumor or of an associated hydrocephalus the tension within the posterior fossa may be increased to such an extent as to make it difficult to displace the hemisphere sufficiently to expose the tumor without using undue pressure. Just as soon as the dural flap is reflected the cerebellar hemisphere is protruded through the opening and may project a centimeter beyond the plane of the dura. Under such circumstances exploration of the depths of the fossa will be either impossible or unsafe, unless some measures are adopted to relieve the tension. There are three such measures: tapping the lateral ventricle, removal of a portion of the cerebellar tissues, or the enlarging of the bony opening so as to include the opposite side. The first of these is of service only when the ventricle is distended; the second, which, though quite feasible, and so far as my experience goes has not been attended with any serious disturbance of function, has its objectionable features, and certainly should not be resorted to as a routine procedure. Of the three proposals, the safest, and at the same time the most efficacious, is the last, namely, a bilateral craniectomy. This enables the hemispheres to be displaced with greater freedom, and affords not only a satisfactory exposure, but sufficient room to conduct the subsequent steps of the operation.

FIG. 469.—SHOWING THE POSITION AND DIRECTION OF THE INCISION FOR EXPOSURE OF TUMORS IN THE CEREBELLO-PONTILE ANGLE WHEN IT IS NECESSARY TO UNCOVER BOTH CEREBELLAR HEMISPHERES (BILATERAL SUBOCCIPITAL CRANIECTOMY).

It is one thing to expose a tumor of the auditory nerve and another to remove it. In some of the fatal cases death has been attributed to injury; in one instance to a hemorrhage of the pons inflicted by the operator while extracting the tumor. The tumor should be extracted with instruments, not with the fingers of the operator.

It is especially in the removal of the tumor of the posterior fossa that the two-stage operation is a justifiable procedure. Despite the statements to the contrary, patients with these lesions are not favorable subjects for operation, and inasmuch as a suboccipital craniectomy (bilateral) is in itself a somewhat formidable procedure, without the

exploration or removal of the tumor, there are many instances in which the condition of the patient will be such as to prompt the operator to put off the final steps for a week or ten days, at least until the patient has fully recovered from the preliminary procedure. When the tumor has been removed, the wound should be closed with tier sutures, first, the dural flap, then the fascia, and, finally, the skin. Provision must be made by a stab opening for the escape of such blood as will ooze from the operative field for the first twenty-four to forty-eight hours. As soon as the bleeding has ceased, the drainage material should be removed. The sooner this is removed the better, as the establishment of a sinus in this region is particularly to be avoided, because there is a tendency for cerebrospinal fluid to escape in very much larger quantities than from wounds in the anterior or middle fossa. The continuous discharge

FIG. 470.—PHOTOGRAPH OF THE BASE OF THE BRAIN IN WHICH WILL BE SEEN IN SITU A TUMOR OF THE CEREBELLOPONTILE ANGLE. (Specimen loaned by Dr. William G. Spiller.)

of large quantities of cerebrospinal fluid is not always well borne by the patient.

Neurofibroma of the Acoustic Nerve.—While constituting one of the two indications for exposure of the auditory nerve, acoustic neurofibroma is usually classified with tumors of the cerebellum, especially those of the cerebello-pontile angle. Because of its benign nature, with all the characteristics of a benign growth, it would seem to offer splendid opportunities for surgical intervention, but to offset these there are many obstacles of a serious nature to its successful removal, and not the least of them is its proximity to the vital centers in the medulla. The acoustic neurofibroma springs from the nerve at the point of its emergence from the junction of the pons and medulla. It is usually nodular, grows very slowly, never attains large proportions,

may be bilateral, and is encapsulated. It is loosely attached to the surrounding structures and may be readily enucleated. Without entering into a discussion of the symptomatology, it may be said that the acoustic tumor syndrome is well defined and that the diagnosis may be made in many instances with practical certainty (Fraenkel-Hunt). Exceptionally, however, the association of an internal hydrocephalus may be a confusing element, and in some instances it may be mistaken for slowly growing tumors, taking their origin from other structures in the immediate vicinity. As to the relative frequency of neurofibromata there are no available statistics. It is not as common as other tumors of the posterior fossa. I have seen but one case, and in this the condition of the patient was such that an accurate diagnosis could not be made; the tumor was discovered at the autopsy.

Tinnitus Aurium and Vertigo.—While the auditory nerve is brought into view in every exploration of the posterior fossa for tumor, and especially of the pontile angle, it was not until 1902 that the idea of deliberately dividing the nerve as a therapeutic measure was suggested. Krause proposed the operation as a means of relieving persistent tinnitus aurium and persistent vertigo. Since that time 8 operations have been recorded, viz., those of Krause, Wallace, Milligan (2 cases), Bryant, Ballance, Parry, and Frazier. It occurred to Mills that section of the auditory nerve might be useful also in other perversions of the function of that nerve, such as persistent vertigo, and the first operation with this end in view was performed in October, 1908.

Just as epileptiform tic in the territory of the fifth nerve may be cured by dividing the nerve or removing the Gasserian ganglion, so persistent vertigo and tinnitus may be relieved by division of the auditory nerve. As Ballance says, we may hope in this operation to be able to spare the nerve of Wrisberg, which is in no way concerned with the auditory symptoms, just as it may be possible in dividing the trunk of the fifth nerve to spare the motor root.

Indications.—In most instances the patients are deaf, so that there is no serious objection to sacrificing the nerve. In cases of persistent vertigo benefit has been derived from removal of the semicircular canals, but this operation will in no way affect the tinnitus. The cochlea must be destroyed or the cochlear division of the nerve divided. The appropriate cases are those in which the disease is labyrinthine; it may originate in the cochlear ganglion, in the vestibular ganglion, or in both, but as there is no means as yet of separating the cochlear from the vestibular division, the auditory trunk must be divided. Tinnitus of central origin would not be influenced by this operation; the condition must be due to some lesion in the peripheral distribution of the nerve. According to W. S. Bryant, the most promising cases are those with marked loss in air conduction with preservation of bone conduction, cases with definite cochlear lesions in which the tinnitus is low pitched and of varying character. High-pitched and musical tinnitus, with complete deafness in both air and bone conduction, he regards as contraindications.

Operative Records.—Of the 8 operations on record, 3 died, Milligan's on the third day, Krause's on the fifth, and Wallace's three weeks after the operation. One of Milligan's cases and those of Parry, Bryant, Ballance, and Frazier survived the operation. In none can it be said that the patient was entirely relieved, although in all was there considerable relief. In this small group the mortality has been unnecessarily high. If the proper technic is adopted, and the operation conducted by those who are thoroughly familiar with the difficulties attending operations in the posterior cranial fossa, the mortality should be no higher than after operations upon the Gasserian ganglion or its sensory root. In the operations about to be described in some an attempt was made to approach the nerve through the middle fossa, and the operators experienced no little difficulty.

Wallace and Marriage, in a case on which they operated, first performed a complete mastoid operation, in which the posterior wall of the auditory meatus was removed as far as the level of the facial canal and the lateral sinus exposed. Upon working down and back from this point, the dura was exposed over the cerebellum for three-fourths of an inch beyond the lateral sinus in order to leave sufficient space in which to retract the cerebellum. The temporal bone, which formed the inner wall of the mastoid, was removed. An incision about 1 inch long was then made into the anterior edge of the dura, and a flat retractor, conveniently bent, was introduced, and the cerebellum compressed until the auditory nerve appeared running obliquely into the internal auditory meatus. By this approach the facial nerve is not usually seen, as it lies internal to the auditory nerve and, therefore, deeper, but pressure upon the eighth nerve close to the brain will usually bring the facial nerve into view. A blunt hook can then be easily passed around the auditory nerve without danger of doing any damage to the facial, and the auditory then may be either divided or extracted.

The patient upon whom they operated was improved, though unfortunately he died three weeks later, and at autopsy it was found that a small strand of the eighth nerve had not been divided.

R. H. Parry in his operation made an osteoplastic flap which extended from the middle of the zygoma to the base of the mastoid, opening the middle fossa. The dura was separated as far as the semicircular canal and then opened. The roof of the auditory meatus was removed, and in it were the auditory and facial nerves. The auditory was divided, and unfortunately the facial was torn by a piece of bone. The patient made an uneventful recovery and the vertigo and tinnitus from which he suffered were greatly lessened.

Krause entered the skull through an osteoplastic flap in the occipital region. Upon dividing the dura and displacing the hemisphere the seventh and eighth nerves came into view. The auditory nerve was divided, but five days later the patient died from pneumonia. In this short interval the tinnitus was better and the dizziness had entirely disappeared.

W. S. Bryant, after numerous observations upon the cadaver,

recommends an approach through the middle fossa of the skull. A U-shaped incision with base upward is made down to the bone; the anterior limb of the incision is on a line with the posterior portion of the mastoid process, extending upward about 1½ to 2 inches above the center of the lateral sinus, and the posterior limb 1½ inches behind the anterior one. The underlyng bone is removed by a rongeur forceps forward as far as the superior angle of the petrous bone and downward to the lateral sinus. The dura is incised, the cerebrum elevated, and the superior semicircular canal sought. An incision is made in the tentorium parallel to, but behind, the edge of the petrous bone, in order to avoid the superior petrosal sinus. The cerebellum is displaced backward, and the auditory nerve is seen lying at the bottom of the wound. He has performed one operation upon the living subject, and while the patient recovered from the operation he was only slightly improved.

In 1905 Milligan divided the auditory nerve by approaching the internal auditory meatus through a large osteoplastic flap in the temporal region. The temporosphenoidal lobe was gradually displaced, and by working above along the posterior surface of the pars petrosa the nerve was reached. The operation was very difficult and tedious, but the patient, though severely shocked, ultimately recovered and left the hospital greatly improved. In 1906 Milligan again divided the auditory nerve for severe tinnitus in a woman aged forty-six, who had twice threatened to take her life. The nerve was approached through the masto-occipital bone and the operation completed in one stage. The patient never rallied, and died three days afterward. The displacement of the cerebellum he found a real and practical difficulty.

In Ballance's case the patient was a woman forty-nine years of age who for two years had complained of tinnitus, vertigo, and nausea. The removal of the semicircular canals on a previous occasion had relieved altogether the vertigo, but had no effect upon the tinnitus. In a two-stage operation Ballance exposed and divided the auditory nerve. In displacing the hemisphere, the fifth, seventh, eighth, ninth, tenth, eleventh, and twelfth nerves were readily exposed. In this case the seventh nerve was easily isolated from the eighth and no attempt was made to sever the nerve of Wrisberg. Convalescence was very slow and interrupted by occasional attacks of syncope and feeling of impending suffocation. Two months after the operation there was slight paralysis of the right palate and of the pharynx, with nystagmus and absolute deafness, but no anesthesia or ataxia. Five months after the operation the painful tinnitus had entirely disappeared, and apart from a slight deviation of the tongue, the patient had almost fully recovered from the effects of the operation.

On October 6, 1908, Frazier divided the auditory nerve through a suboccipital opening for the relief of persistent vertigo in a woman sixty-four years old. The exposure was made as for exploration of the cerebello-pontile space. After reflecting the musculocutaneous flap, removing the underlying bone, and turning down a dural flap, the

auditory nerve was approached from the lateral aspect, following the direction of the petrous bone. The nerve was readily exposed, but it was with considerable difficulty that it was isolated from the facial nerve. Ordinarily when these two nerves are put on the stretch by displacing the cerebellar hemisphere backward, the nerves are separated sufficiently to differentiate one from the other. This method, however, was not successful in this particular case, and in order to distinguish one from the other electric stimulation of the facial nerve was resorted to. Apart from this troublesome feature the operation was attended with no difficulty. The patient stood the operation well and on her discharge from the hospital the vertigo was less marked. The condition, however, was by no means entirely relieved.

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ADDENDUM ON THE MEANS OF OPENING THE SKULL.

By W. W. Keen M.D.

Dr. W. H. Hudson, of Atlanta, Georgia, has devised some burrs (Figs. 471–473) and forceps (Fig. 474) which, so far as I know, sur-

Fig. 471.

Fig. 472.

Fig. 473.

Figs. 471–473.—Hudson's Burrs.

pass all other means for making an osteoplastic flap. They combine the safety of the chisel and the speed of the various mechanical saws, whether driven by hand or by power.

The burrs (Figs. 471 and 472) are to be used in succession. They are peculiar in this respect, that *so long as there is any resistance* the blades, which are *spiral cutting blades*, will very rapidly cut their way through the skull, but *so soon as resistance ceases—i. e., so soon as the dura is reached*, or even a very thin layer of bone on the inner surface of the skull which yields to pressure—*the instrument ceases to advance*, for the brace can no longer be turned. Be the skull thin or thick, the burr will cut rapidly until it is nearly or barely through and then stops. When the middle meningeal artery is in the path of the burr, if it lies even in a shallow groove, it will be pushed before the advancing burr and will not be cut (so Dr. Hudson claims—I have had no personal experience with this condition). If it lies in a groove which is nearly closed or in a complete canal its division is unavoidable, no matter what instrument is employed.

The other two globular burrs (a larger and smaller one of the type of Fig. 473) are intended for making larger openings, for decompression

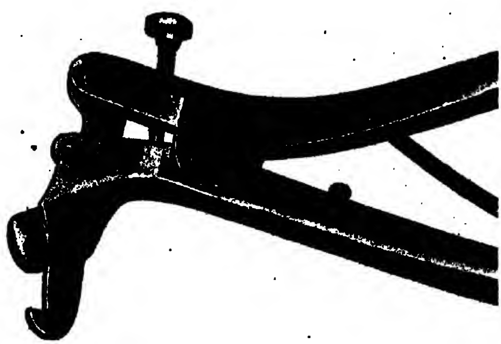

FIG. 474.—HUDSON'S FORCEPS.

and similar operations. These will cut completely through the skull, but Fig. 473 shows a button for the protection of the artery.

Fig. 474 shows one of the forms of forceps. Both blades or jaws have cutting edges, the lower one cutting vertically, the upper with a shear, *i. e.*, obliquely. The upper blade thus obtains a hold or grip on the upper surface of the bone and does not slip. In the other form both blades cut obliquely. Both forms cut very quickly.

In making an osteoplastic flap, Fig 475 shows in outline the method employed by DaCosta, who has used these instruments on several occasions with great advantage. Four openings are made at the broadest part of the proposed flap. In making these openings it is important always to hold the burr vertical to the surface of the skull.

The openings 2 and 3 are about two inches apart. The skull between these two openings is divided by a Gigli saw, the bone being beveled. The beveling of this small portion is amply sufficient for the purpose of supporting the entire flap when it is replaced. From 2 to

1 and 3 to 4 the skull is bitten away by Hudson's or other rongeur forceps. From 1 and 4 the dotted lines show the direction in which the skull is divided also by the rongeur forceps. If it is desired, of course, other openings can be made at the end and the middle of these two dotted lines and the Gigli saw can replace the forceps in making the entire flap if so desired. By using the forceps for the two oblique lines from 1 and 4 any damage to the middle meningeal will not occur until one reaches the lower end of the incision and generally no injury at all will occur.

I gave these instruments, I think, the severest possible test as to danger at a Jefferson clinic on the day before the meeting of the American Medical Association on June 8, 1909. I blindfolded one

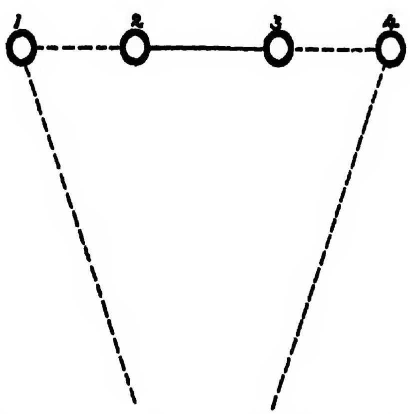

FIG. 475.—SHOWING THE WAY IN WHICH J. CHALMERS DACOSTA USES HUDSON'S BURRS AND FORCEPS.

Four holes are made by the operator. Between 2 and 3 the bone is cut beveled to give support. All the rest of the flap is bitten away by Hudson's or other forceps along the dotted lines and the flap is then fractured. In this way the middle meningeal is very unlikely to be injured. and if injured is injured at the end of the operation.

of the surgeons present who had never used or even seen these instruments before, and, placing the burr over the squamous portion of the temporal bone of a cadaver, asked him to drive it into the brain if possible. After a few turns the brace could not be revolved any further, and on removing the burr, the uninjured dura was exposed at the bottom of the opening. No severer test of its safety, I think, could be devised.

These instruments can be obtained from Charles Willms & Co., Baltimore, and doubtless will soon be made by all competent instrument makers. Any purchaser, however, should be assured by trial on any animal bone, such as the shoulder-blade of a sheep, that the instruments functionate properly.

CHAPTER LXXX.

GENERAL ANESTHESIA AND ANESTHETICS.

By Hobart Amory Hare, M.D.,

PHILADELPHIA.

The term anesthesia was first employed by Oliver Wendell Holmes November 21, 1846, to describe the state of an individual under the full physiologic effect of ether. It is derived from the Greek word *αἰσθανομαι*, with the negative prefix *an*, and if strictly interpreted, means without the ability to feel. Etymologically, the term analgesia is far more correct, but anesthesia is now firmly embedded in medical nomenclature, and is sanctioned by usage. That the state of the patient under one of the drugs used for the production of surgical anesthesia is not one of anesthesia, but that of analgesia, is illustrated by the case of the child cited by Snow, who, while under the influence of chloroform to the extent that it was "cut for stone" without pain, nevertheless had so little disturbance of cerebration and the sense of feeling that it played with a toy.

History.—There can be no doubt that human beings from the earliest times endeavored to relieve the pain of disease, injury, and operation by the use of measures or drugs that would benumb sensation. Pliny tells us that mandragora is taken against cuttings and puncturings lest they be felt, and Apuleius stated that, if any one is to have a limb mutilated, burnt, or sawn, he may drink half an ounce [of mandragora] with wine, and, while he sleeps, the member may be cut off without any pain or sense. The Chinese and East Indians used, in very early times, full doses of cannabis indica for the same purpose. Nor were these ancient practitioners satisfied with the ingestion of the drug by the stomach, but they often produced insensibility to pain by making the patient inhale the vapor of burning cannabis indica; or, in the case of mandragora, from having them smell it. These methods, often combined with the use of intoxicating doses of alcohol, were the only ones employed until the middle of the fifteenth century, when Theodoric produced surgical anesthesia by the use of the "spongia somnifera." This was prepared by boiling a sponge in water to which had been added juices derived from a number of sources, the most important being mandragora, opium, hyoscyamus, and hemlock. When the boiling had been continued until the sponge held nearly all the residue in the vessel, it was placed aside to dry. When needed, this sponge was thoroughly soaked in hot water and placed over the patient's face, who inhaled the fumes until insensible. It is interesting to note not

only that anesthesia by inhalation was produced, but that, after the operation was over, the patient was resuscitated by inhaling vinegar from another sponge, a plan of resuscitation often utilized by modern surgeons to prevent the nausea following ether and chloroform.

Various mechanic devises whereby pressure upon the nerves of a part was brought about was also employed for many hundred years for the relief of pain, and hypnotism was resorted to, but with little success, for obvious reasons. Binz quotes a passage from Paracelsus (who died in 1541), in which Paracelsus recommends for internal use for the relief of pain, in preference to opium, a drug which Binz thinks must have been identical with sulphuric ether. As the discovery of ether is usually credited to Valerius Cordus, who was not born until 1515, it is manifest that the fluid used by Paracelsus could not have been ether, or else that Valerius Cordus was not its first discoverer. Cordus undoubtedly produced ether, but more than two hundred years elapsed before anything further was done concerning it, until Froben, a German chemist in London, made it, but kept the method of its production secret. In 1731 Stahl made ether in Berlin, first calling it "sulphuric ether," thinking that it was a modification of sulphuric acid.

The real history of surgical anesthesia is, however, to be found in the last one hundred years. It is true that Pearson, of Birmingham, England, gave ether vapor in 1795 to diminish the sufferings of advanced pulmonary tuberculosis, but its effects were not sufficient to produce anesthesia or unconsciousness. In 1795 Beddoes, of Bristol, England, recorded experiments in which one dram of ether was inhaled, and advised that pulmonary consumption be treated by inhaling three times a day 1 dram of a mixture of ether, 1 ounce, and cicuta leaves, half a dram, and Crowther reported a case cured by this measure. Thornton reported to Beddoes that he produced unconsciousness by the use of ether in a woman who was suffering from a painful affection of the breast. It is also a fact that Sir Humphrey Davy, in 1798, found that, while he was experimenting with nitrous oxid gas, he was relieved of a toothache, and for this reason he suggested that this gas be used by surgeons for the relief of pain, but his advice was unheeded. In 1818 Faraday stated that the inhalation of ether vapor decreased pain, as did nitrous oxid, and Thompson, of Glasgow, showed his students that if they inhaled this vapor, the pain of minor injuries was not felt. Here, on the threshold of one of the greatest discoveries of modern times, the profession "marked time" for forty-four years, and the step between the partial benumbing of sensation as an amusing experiment, to the production of true anesthesia, was not taken. Indeed, Velpeau, in 1835, said "Eviter la douleur dans les operations est un chimère qu'il n'esè pas permis de poursuivre anjourd'hui!" It is interesting to note in this connection that, although it was stated in 1862 by Mareno y Maiz that coca leaves, if chewed with potash, produced anesthesia of the lips and tongue, it was not until 1884 that Koller introduced cocain as a local anesthetic.

In 1839 a medical student named Clarke, in Rochester, New York,

gave ether vapor to some of his friends to inhale for amusement, and one of them, Morton, three years later (1842), used it to permit him to extract a tooth painlessly. In this same year some students in Anderson, South Carolina, inhaled ether vapor for the purpose of getting drunk, and, while intoxicated, caught a young negro and forced him to inhale so much of it that he became unconscious and apparently dead, greatly to their alarm. The boy recovered, and one of the students told Crawford Long, of Georgia, of the occurrence. Long, in this same year (1842), removed a cystic tumor of the jaw from a patient under the influence of ether, and repeated the experiment a number of times, but he failed to grasp the extraordinary value of the idea, or was too careless to report it at the time. In any event he failed to keep on using the drug. On the other hand, Morton, who had first extracted a tooth for a patient under ether in 1842, as already stated, was alive to the value of the discovery, but it was not until 1846 that he did anything more about it. In that year a chemist of Boston, named Jackson, who was an instructor of Morton, suggested to Morton that some pure ether be prepared and used for surgical purposes. Morton claimed that the ether having been made, he tried it before Jackson did so, and these men ceased to accuse the other of the theft of an original idea only when the grave closed over them. There can be no doubt, however, that Morton deserves the credit for the actual introduction of ether, for in September, 1846, Morton again gave ether and pulled a tooth without pain to the patient, whose prolonged unconsciousness, however, frightened him so much that he did not dare continue his experiments for some days. The critical day (October 16, 1846) at last arrived when he persuaded Warren to let him try the drug in the Massachusetts General Hospital, Boston, in a case of tumor of the neck upon which Warren was about to operate. The effect was so satisfactory that Warren said to his class, "Gentlemen, this is no humbug," and Bigelow exclaimed, with less guarded enthusiasm, "I have seen something to-day that will go around the world." The desire for personal aggrandizement led Morton to try to keep the character of the drug a secret. He called it "Letheon," but its odor soon disclosed its real nature, and on November 7, 1846, he admitted that the drug was sulphuric ether. Finding that he was deprived of a financial reward, Morton then sought the credit for the scientific introduction of the drug, a credit usually given him to-day, although Long's early work and Jackson's labors undoubtedly aided in its introduction.

For obvious reasons the use of ether for anesthesia spread like wildfire. In Philadelphia it was first used by Pancoast in the Jefferson Medical College Hospital, December 19, 1846. In January, 1847, Sir James Simpson first used ether in Edinburgh during the performance of version.

Although Thompson described a crude form of chloroform in 1820, formed by the union of chlorin and olefiant gas, to which he gave the name "Dutch liquid," the true discovery of chloroform is due to Guthrie, of Sackett's Harbor, New York, a surgeon in the United States Army,

who made his report in October, 1831. Liebig discovered it independently in November, 1831, and Soubeiran, in France, did likewise in January, 1832. Although a Dr. Ives, of New Haven, used it by inhalation in the latter part of 1831 in a case of asthma, the employment of chloroform as an anesthetic did not take place until 1847, when Waldie, a chemist of Edinburgh, suggested its use to Sir James Simpson, who took it himself and gave it to some friends in his own house in November of that year. Fortunately, no evil effects followed, for had one of these investigators died, the use of the drug would have been indefinitely delayed. The first patient who was to receive chloroform for operation did not get it because Simpson was detained, but by a strange coincidence died as the first incision was made. Had chloroform been used and death ensued, it would have been regarded as a deadly drug. The first actual use of chloroform for surgical purposes was by Simpson in the Edinburgh Royal Infirmary on November 17, 1847.

Nitrous oxid was known to possess intoxicating properties many years before it was used as an anesthetic. Its inhalation caused the individual to become hilarious, or his antics caused others to laugh, hence the term, "laughing gas." On December 10, 1844, a dentist of Hartford, Conn., named Horace Wells, noticed that a man named Cooley, who had taken the gas for amusement, felt no pain when he fell and hurt his leg. On the next day (December 11th) Wells inhaled the gas himself and had a molar tooth painlessly extracted. He at once recognized the value of the discovery, and tried it with ether successfully in other dental cases. He persuaded Warren, as did Morton two years later, to let him give the gas in the Harvard Medical School, but because he did not provide enough gas he failed to cause anesthesia, and was hissed and hooted out of the building by the students. Wells died in 1848. With his death nitrous oxid fell into desuetude, and it was not until Colton published his epoch-making report of 20,000 successful inhalations in 1867 that the gas took its place as a standard anesthetic.

General Considerations.—Notwithstanding the well-recognized fact that the older anesthetics possess many disadvantageous qualities, and that experimenters have endeavored unceasingly to invent substitutes that would prove better, it nevertheless is true that, from the standpoint of reliability, safety, and general applicability, ether and chloroform are still *facile princeps.* There is only one other anesthetic which is safer, namely, nitrous oxid, and this gas, to use the expression often applied to machinery, is not flexible enough. That is to say, it does not meet almost every need of the general surgeon, as do ether and chloroform.

It is not possible to discuss all the drugs that have been tried as anesthetics, nor all the mixtures of drugs of various physiologic effects and various volatility. In this article the only anesthetics which will be included are—(1) Ether; (2) chloroform; (3) nitrous oxid; (4) ethyl chlorid; (5) ethyl bromid, and, lastly, those mixtures of these drugs which are largely used by some surgeons.

Before taking up each individual drug it is wise to discuss certain general facts as to surgical anesthesia. In the first place, it may be laid down as an axiom that the use of an anesthetic in some form is to be resorted to in all surgical procedures that cause pain unless the pain be very moderate or the operation very brief indeed. Even if the operation be brief, if it is distinctly painful, anesthesia is advisable, because it is humane and because it not only relieves ordinary pain, but distinctly decreases the mental perturbation and nervous shock, both of which are important factors in the near and the remote lifetime of the patient. Although local anesthesia may be adequate in many minor surgical procedures, the mere relief of pain is not all that is needed if the operation is one which engenders fear on the part of the patient, for one of the blessings of surgical anesthesia is the production of unconsciousness.

There is probably only one state which distinctly contraindicates a general anesthetic, namely, well-developed diabetes mellitus, in which diabetic coma nearly always follows. There are, however, a large number of conditions in the face of which the wisdom of using an anesthetic drug must be carefully debated. In some of these it is distinctly unwise to use any of the general anesthetics in the great majority of instances, as, for example, when operations are performed for goiter, in the occasional profound collapse or shock from perforation of the bowel in typhoid fever, and in cases of cardiac and renal disease, when anasarca and pulmonary edema threaten to close the scene. On the other hand, even the presence of well-developed cardiac disease is an indication rather than a contraindication for the use of a properly selected anesthetic. I have repeatedly seen patients, on whom an operation was attempted without a general anesthetic, become cyanotic and distressed because of fear of its effects, but immediately improve if ether was skilfully given, the ether not only removing painful impressions and mental distress, but also acting as a cardiovascular stimulant. So, too, the fact that a patient has nephritis does not contraindicate the use of an anesthetic. On the contrary, if an operation is essential to save life, the chances for such are in many instances greater if an anesthetic is employed.

Each case must be considered by itself, not only as to the gravity of the morbid lesions which may be present, but also from the standpoint of which drug will be the safest in view of the existence of such lesions. Anesthetic drugs are given too largely as a matter of custom or routine. In the temperate zone, where the climatic conditions permit the use of all the drugs used for the production of surgical anesthesia, a careful choice should be made for each case which comes to operation. In hot climates chloroform must be the choice nearly always because of the high volatility of ether. At present ether is used almost to the exclusion of every other anesthetic in many of the large operating clinics of the northern United States, and chloroform is still equally popular in England and on the European continent; although the recognition of the value of ether is becoming more wide-spread in both these areas.

As Luke well says: "We are surely bound to use the safest anesthetic which we possibly can for any given operation, taking all the circumstances of the case into consideration, and we have no right whatever to give chloroform to a patient for the extraction of teeth when nitrous oxid is available, and we are in duty bound to give ether rather than chloroform for a curettement if there is no contraindication to ether in a given case. At the same time, unreasonable or unreasoning bias is to be avoided, and, if an operation on the brain or about the face is to be performed, we are equally bound to administer chloroform, as in this case the immediate necessities of the operation must be foremost in our mind, and the high death-rate from chloroform must not make us frightened to use it, where there is such a clear indication."

A vast army of statistics as to the relative safety of chloroform, ether, and nitrous oxid has been assembled. These show that the death-rate from their use is about as follows:

Chloroform............	1 death in	2500 anesthesias.
Ether.................	1 death in	16,000 anesthesias.
Nitrous oxid	1 death in	200,000 anesthesias.

The peculiar limitations of nitrous oxid prevent us from employing it universally, and the fact that ether is far safer than chloroform makes it the anesthetic of choice in ordinary conditions. There are, however, certain contraindications to the use of ether which necessitate its being put aside. The first of these is any state of advanced degeneration of the blood-vessels, such as atheroma and aneurysm, in which states the great increase in arterial tension produced by ether may cause rupture of a vessel. (See Preparation of Case for Anesthesia.) The second contraindication is any acute inflammation or irritation of the kidneys or chronic parenchymatous nephritis, particularly if red blood-cells are in the urine. In such cases the use of much ether will be deleterious to the renal tissues. The third contraindication occurs in some cases of operation upon the brain or abdominal contents, in which cerebral congestion, on the one hand, with high blood pressure or vomiting, on the other, may complicate the operation or produce serious postoperative difficulties. A fourth contraindication occurs in operations upon the nose and mouth, in which the necessity of giving ether constantly interferes with the operative procedure or produces profuse secretion of mucus and saliva by reason of the irritant fumes of the drug. Fifth, ether is contraindicated or must be used with caution in persons who are suffering from acute or chronic bronchitis with excessive secretion, since its vapor may cause so much irritation or produce such an excess of secretion as to interfere with respiration during or after operation. It has been taught that ether is absolutely contraindicated in cases which suffer from emphysema of the lungs, chronic bronchitis, bronchiectasis, or pulmonary tuberculosis. There can be no doubt that all these conditions are, in the majority of cases, unfavorably influenced by this anesthetic. On the other hand, such patients not rarely suffer from

associated cardiac weakness, and if this is the case, chloroform may be the more dangerous drug. If ether is given by the drop method and with great caution, I believe it is much the safest anesthetic of the two in the presence of cardiac lesions. Sixth, ether should be avoided in the case of children or adults in whom ether, on a previous occasion, has acted deleteriously upon the lungs or kidneys, and, seventh, it is to be recalled that alcoholics are not favorable subjects for the use of ether, because it produces anesthesia only when used in very large or excessive amounts.

On the other hand, there are a number of conditions in which the known physiologic action of ether makes it distinctly the drug of choice. Any feeble condition of the heart in a patient requiring operation will probably be benefited by the effect of the drug, if it be given skilfully, and it is hardly necessary to add that the utmost skill in administration will often be necessary in the presence of such lesions.

The conditions which exclude chloroform, as a rule, are, first, myocardial degeneration, cardiac dilatation, and any state which causes distinct cardiac feebleness or severe cardiac fatigue, as, for example, pulmonary emphysema and asthma. It is also dangerous in valvular disease with ruptured compensation or in cases in which the heart is on the borderland of ruptured compensation. If valvular disease with compensatory hypertrophy is present, chloroform may be used if the cardiac first sound is clear, but it is not the anesthetic of choice. Aortic regurgitation strongly contraindicates its employment. Additional contraindications are a state of poor nutrition, as in those suffering from prolonged suppuration or diabetes mellitus. Lymphatic patients are poor subjects for the use of chloroform. (See Delayed Chloroform Poisoning.)

On the other hand, chloroform, because of its known physiologic effects, often is the remedy of choice. This is notably the case in instances of arterial spasm causing very high arterial tension, and in which the heart is hypertrophied to meet the strain. In such a case the chloroform, if given with care, will lower tension instead of raising it to an undue degree, as does ether, and therefore prove useful. Again, given a case of nephritis, new or old, chloroform is the drug of choice in most instances because, although quantity for quantity it is far more irritating to the kidneys than ether, it requires so little chloroform, relatively, to cause anesthesia that its effect is less irritating to the kidney than is that of ether. A very large number of investigations upon animals and upon man have been carried out to determine the influence exercised by chloroform and ether upon the kidneys. In many instances the results have been conflicting, but at the present time it may be stated that during the early stages of the administration of chloroform the urinary flow is often increased, although when full anesthesia is developed secretion is usually diminished and rarely suppressed. After the anesthetic is withdrawn, it is found that there is a great increase in urinary flow, amounting to four times the normal volume in the same period of time, and this increased flow is maintained

for several hours. The nitrogen content of the urine is, however, greatly reduced, and there is also a reduction in nearly all its solids. In cases in which the chloroform is administered for a long time there may be a considerable outwandering of leukocytes into the renal tubules, these leukocytes eventually escaping in the urine. Thompson[1] believes that this diapedesis is the result of stasis in the blood-vessels of both the glomeruli and the tubes, rather than from any irritation of the kidney itself. The only ingredients of the urine which are markedly increased by the elimination of chloroform are the chlorids, which appear in far greater quantity than normal, both during and after its administration. Thompson asserts that after the drug is stopped the amount of chlorids in the urine may be ten times the normal quantity. Albuminuria from previously healthy kidneys occurs in a very small percentage of cases, but reducing substances other than glucose may be present in the urine in considerable quantity. Their nature has not yet been determined.

The effect of ether on the kidneys during the first stages of its administration is usually a diminution in the quantity of urine, and if the drug is pushed, the diminution in secretion becomes more marked than when chloroform is given. If excessive quantities of ether are used, suppression of urine may be produced. The nitrogen elimination in the urine is also diminished, but not so greatly as when chloroform is used. Ether also causes a greater outwandering of leukocytes into the urine than does chloroform, but here again Thompson is of the opinion that stasis in the kidney rather than the irritation is the cause for this outwandering. The chlorids are increased, but not nearly so much as they are under chloroform. Transient albuminuria is far more commonly met with when ether is given than when chloroform is used, but reducing substances after the use of ether are not so constantly present.

The Preparation of the Patient for Anesthesia.—Unless the need of operative procedure is most urgent, a period of not less than twenty-four hours should be set aside for the careful preparation of the patient. During this time, and if possible for several days before this, the urine should be frequently examined, first, to determine whether the kidneys are healthy, and, second, to discover the presence of glycosuria or diabetes. The urine should also be measured in order that it may be discovered if its quality is normal, since, if it is scanty, renal complications are much more prone to occur than if it is freely secreted. In many cases in which the urine is scanty, unless its scantiness depends upon nephritis, the free administration to the patient of pure water in sufficient quantities to flush the kidneys will be all that is required. The efficiency of the water may be increased by adding either bicarbonate of potash or citrate of potash, in small quantities, not more than 20 or 30 grains being taken in the twenty-four hours, since potash salts, if given in large quantity, act as circulatory depressants. Should a more active diuretic be desired, small doses of sweet spirit of niter may be added to the draft, since this simple remedy acts as an efficient

diuretic in many cases, overcoming any tendency to spasm of the renal vessels, and flooding these organs with blood.

Not only should the urine be examined chemically, but also microscopically. Indeed, the microscopic examination may be the more important of the two, for the presence of albumin does not necessarily prove the existence of severe renal disease, whereas the finding of granular, waxy, or hyaline casts in great number would indicate that the patient is not in a fit state for the use of an anesthetic. This is particularly true of large granular casts and blood-cell casts, indicating the presence of parenchymatous nephritis.

There can be no doubt that insufficient attention at the present time is paid to the state of the circulatory system, particularly in persons beyond forty years of age. It is true that the heart is usually examined to discover the presence of a murmur, and not infrequently the finding of a murmur is considered as an adequate reason for questioning the use of an anesthetic. As a matter of fact, the presence of a murmur, if associated with compensation, is no contraindication to the employment of an anesthetic, nor is cardiac hypertrophy a contraindication. On the other hand, the discovery of cardiac dilatation, with or without a murmur, is a contraindication, and, if possible, should be overcome by proper treatment before the anesthetic is used. If the first sound of the heart is weak and time suffices, small (not large) doses of digitalis or strophanthus should be given during a period of a week or ten days, not so much with the object of powerfully stimulating the heart, as of improving its nutrition and thereby putting it in better position to withstand the anesthetic and the effects of the operation. Another very important circulatory condition almost universally ignored by surgeons is the state of arterial tension. In a fairly large proportion of patients coming to operation after the fortieth year arterial tension is above normal, due in part to spasm and in part to arteriocapillary fibrosis. This high tension requires of the heart far greater effort than exists in health, and, therefore, it not infrequently happens that before the anesthetic is given the patient's heart is distinctly fatigued. Added to this fatigue is the additional effort due to the increased spasm produced by mental anxiety, and after ether or nitrous oxid is employed the great rise of blood-pressure produced by these drugs throws a still greater burden upon the heart. In all cases where time suffices a careful estimation of the blood-pressure should be made, if possible, with the sphygmomanometer, and if it is found to be abnormally high, it should be brought to approximately natural limits by the use of the nitrites. If tension is decidedly above normal and time does not suffice for a prolonged course of the nitrites, a hypodermic injection of nitroglycerin ($\frac{1}{100}$ to $\frac{1}{50}$ grain) should be given before and during the operation. On the other hand, if a condition of hypotension is present, strychnin and digitalis should be used for some days before the operation, and strychnin should be given immediately before the anesthetic is given to prevent hypotension developing to a dangerous degree. If more attention were paid to blood-pressure prior to operation, fewer

cardiac, pulmonary, and renal complications would be credited to the evil effects of the anesthetics employed.

A number of researches have shown that the administration of ether and chloroform diminishes hemoglobin materially. In other words, the color index is decreased. J. Chalmers DaCosta concludes from his investigation that ether produces increased hemolysis. There can also be no doubt that the duration of the anesthetic state and the amount of ether used directly influence the blood changes. For many years it has been generally recognized, both because of clinical experience and experimental research, that profound anemia contraindicates the administration of the ordinary anesthetics. Surgeons generally hold that when the hemoglobin is below 50 per cent. it is dangerous to give ether or chloroform. This rule is a wise one to follow, and should be abrogated only when some vital emergency exists. Mikulicz, however, puts 30 per cent. hemoglobin as the lowest level at which operations are to be attempted. There are cases, of course, which have been successfully operated on at a still lower level, but complications during the operation or immediately after it are so prone to occur and are of so serious a nature that the patient's life is distinctly in jeopardy. The danger of administering an anesthetic to an anemic patient is greater when the anemia is chronic and depends upon some disease of the blood-making organs than when it is acute, as the result of hemorrhage. In either instance, however, oxygen should be given during the administration of the anesthetic, if possible, and administered freely for some time after the anesthetic is stopped, in order speedily to resuscitate the patient.

The introduction of large quantities of normal saline solution into the veins with the idea that arterial pressure will thereby be raised is, of course, futile. If the solution is given hot, the heat may act as a stimulant, or the saline constituents may produce such an influence, but the volume of the fluid itself does not do so. On the contrary, the use of venous injection or hypodermoclysis, whereby a large quantity of fluid is placed in the patient's body, serves to burden the heart and to be provocative of pulmonary edema.

Prior to the use of any anesthetic by inhalation, and particularly if ether is to be employed, the patient should not receive any food for four or five hours before the operation, since an empty stomach is one of the most efficient preventives of vomiting during or after the administration of the drug. The common method of starving a patient for a great number of hours prior to the administration of an anesthetic seems to be conclusively proved to be deleterious by the investigations of William Hunter in 1908 (London Lancet., 1908, i, p. 993). Hunter believes that the vomiting is not of nervous origin, but essentially toxic, and due chiefly to interference with the liver by the drug. This influence of chloroform upon the hepatic function is much more prone to occur in a liver already weakened by disease or by poor nutrition.

There can be no doubt that the absence of food from the stomach during the administration of anesthesia is always advantageous, but

there can be also no doubt that it is not essential to starve the patient for twelve or eighteen hours before the drug is given. Easily digested gruels of barley or rice can be given in small quantities up to within two or three hours of the operation with distinct advantage, particularly if their digestion is hurried by the use of takadiastase or pancreatin. These starchy gruels have the advantage that they permit the liver to store up glycogen, and thereby place it in a favorable position for the maintenance of its function; whereas animal broths not only fail to do this, but throw an undue strain upon the kidneys in the elimination of extractives. As Hunter also points out, a deficiency of carbohydrates or glycogen in the liver-cells results in increased destruction of protein material, and this, in turn, causes the formation of toxic products. Again, Hunter believes that the absence of glycogen from the liver, by diminishing the combustion processes in that organ, diminishes the antitoxic powers of the liver-cells so that the starved individual is more easily affected by poisons than the well-fed or glycogen-rich person. So, too, an absence of carbohydrate material results in extensive changes in fat metabolism, which results in an increased formation of acid, and so tends to the development of acidosis.

In this connection it is interesting to note that Rosenfeld and Beddard both hold that chloroform poisons the hepatic cells in such a way that their metabolic processes are altered to the extent that while they can utilize carbohydrates, they can but imperfectly deal with proteids, and even less with fats, and, therefore, as soon as the cells have used up their carbohydrates or glycogen, their hungry condition causes a breaking down of tissue proteid and a transference of fat to them, but since neither of these food-stuffs, and especially the fat, is properly utilized, the cells remain in a condition of severe starvation and so rapidly die. Beddard also quotes Rosenfeld and others as having proved that if the poisoned animal is fed with dextrose, the transportation of fat does not occur, because it is not necessary, and also that recovery is much more likely to take place than when the animal is starved. His deductions, therefore, are closely allied to those which we have already quoted. Not only should patients be well fed with carbohydrates prior to the anesthesia, but it is advisable to feed them freely with dextrose by the mouth or by enema if any symptoms follow the use of the anesthetic. Beddard even goes so far as to suggest that a 6 per cent. solution of dextrose be intravenously injected in urgent cases of delayed chloroform poisoning, treating the case in the same manner that we would treat diabetic coma.

In operations upon the stomach this viscus must be not only empty of food before the operation, but must be carefully washed out, by means of the stomach-tube, by boric acid solution, by normal saline, or with pure water. Indeed, some surgeons make it a practice to wash out the stomach with a stomach-tube before all abdominal operations, claiming that by so doing the chances of vomiting are diminished. In my experience the passage of the stomach-tube in a person who is unaccustomed to its use prior to the administration of the anesthetic

not infrequently produces so much irritability of the vomiting center and of the pharynx that the tendency to vomit is greatly increased, rather than diminished. It is hardly necessary to add that the patient's bowels should be well opened by means of some mild laxative several hours before the anesthetic is used, and if the tongue is foul and the liver torpid, small doses of calomel sufficient to stimulate the liver, without weakening the patient by active bilious purging, are advisable. Under these circumstances it is usually best to give a saline to sweep the bile out of the duodenum, since if this is not done, the retching of the patient may draw into the stomach the freely secreted bile, which, in turn, will increase nausae and vomiting.

Whenever an anesthetic is given by inhalation, the patient should be directed carefully to rinse the mouth with some mild antiseptic solution, such as hydrogen dioxid, one part to three of water, or a weak solution of potassium permanganate. These solutions should be drawn between the teeth and used as a gargle in order to cleanse the mouth and fauces. Not infrequently the mouth of the patient is exceedingly foul, and it is a well-known fact that almost every form of micro-organism, pathogenic and benign, is found in such a mouth. Sensitiveness of the larynx being removed by the anesthetic, tiny particles of decomposing food from between the teeth, or decomposed epithelium and droplets of mucus and saliva, laden with germs, readily gain access to the trachea and bronchial tubes, and without doubt produce complications in the lungs in a large number of cases in which the anesthesia is considered the direct cause of the pulmonary lesion. These antiseptic precautions as to the mouth should be extended to the nasal chambers if they are found to be unhealthy, and are particularly important in those of advanced years who have bad teeth and also those who have chronically enlarged tonsils, with foul secretions in the crypts.

Prior to the administration of any anesthetic by inhalation the anesthetizer must carefully examine the patient's mouth to determine that there is no foreign body present, such as tobacco, chewing-gum, particles of food, or false teeth. If this is not done, a foreign body may be drawn into the larynx, with serious results. The clothing about the chest and throat should be well loosened in order that it may not impair the respiration or the circulation of the great vessels of the neck.

If possible, the room in which the anesthetic is given should be a different one from that in which the operation is to take place, in order that the preparations of the surgeons and nurses shall not alarm the patient. Care should be taken that this room is also quiet and that persons do not pass in and out or slam doors. In other words, every effort should be made to surround the patient with the conditions conducive to ordinary sleep, since by this means artificial sleep is more easily induced.

There can be little doubt that the mental condition of the patient does not receive enough attention from the average anesthetizer, to

whom the constant administration of the drug becomes a matter of routine. It is remarkable that patients whose thoughts are made to run in pleasant channels as the anesthetic is first given usually take the drug more quietly than those who inhale it in a condition of mental distress. This is particularly true of nervous women and children. When the fears of a patient who is conscious are developed into the terrors of semiconsciousness, in which the patient may imagine that the most frightful accidents are taking place, it can readily be understood that profound nervous shock is produced. Any one who has suffered from a nightmare, and studied his mental and nervous condition on awakening from it, will appreciate what marked functional changes can be caused by mental disturbance. For the purpose of diminishing mental anxiety and to shorten the period of consciousness and unconsciousness under the influence of either ether or chloroform, many surgeons administer a hypodermic injection of morphin, varying from $\frac{1}{8}$ to $\frac{1}{4}$ grain, and some combine with this atropin, in order to prevent circulatory failure. More recently many surgeons have employed a mixture of morphin and scopolamin, the latter drug being much more sedative than atropin, in addition to possessing the physical action of the alkaloid of belladonna. Both atropin and scopolamin distinctly decrease the tendency to profuse secretion of saliva and mucus, and so prevent the development of cyanosis, due to mechanic obstruction to the entrance of air into the vesicular portions of the lung. (See Morphin-scopolamin Anesthesia.)

The Care of the Patient During and After the Administration of the Anesthetic.—In addition to a plentiful supply of fresh air in the operating-room, it is essential in many cases that the body heat be maintained by artificial means. Too often the patient's body is separated from the glass top of the operating-table by a very thin blanket or sheet, and not infrequently this cover soon becomes wet with irrigating fluids, or by the water which is used in scrubbing the part which is to be operated upon, with the result that the patient's back is unduly exposed to cold and wet. In such a case pain in the back, congestion of the kidneys, and of the bases of the lungs is usually credited to the anesthetic instead of to exposure. In feeble patients it is better to maintain body heat by the use of warm bottles or warm-water bags rather than to cover the chest and limbs with heavy clothing, which will oppress the breathing.

For the purpose of meeting circulatory and respiratory emergencies a hypodermic syringe, already charged with $\frac{1}{20}$ gr. of strychnin and $\frac{1}{100}$ gr. of atropin, should be at hand, and adrenalin and hot normal saline should also be ready for immediate use by intravenous injection. (For details as to these measures see article on Chloroform.)

The employment of a faradic battery for the purpose of resuscitating the patient who has suffered from collapse during the administration of the anesthetic is, in my opinion, almost of no value. While it is true that the employment of a strong current of faradic electricity swept over the body will produce a reflex effect which may stimulate the

vasomotor and respiratory center during moderate anesthesia (the anesthesia being due to the cerebral effect of the drug rather than upon an influence on the spinal cord), it is also a fact that if so much of the anesthetic drug has been employed that an accident has ensued, the reflexes are largely, if not completely, abolished, and therefore electricity fails to arouse these important physiologic functions. Many years ago Dr. Edward Martin and myself, in an original research,[1] showed that the practice of placing one electrode of a faradic battery over the diaphragm and another over the phrenic nerve in the neck, with the idea of producing diaphragmatic contraction, is entirely futile, irrational, and even capable of doing harm. In the first place, the rapidly interrupted faradic current, if it acts at all, produces a persistent spasm of the diaphragm, and a diaphragm fixed in spasm is as useless as a diaphragm inert from relaxation. In the second place, it is practically impossible to stimulate the phrenic nerve without the current diffusing to the vagus nerve, which lies close by, and so possibly causing inhibition

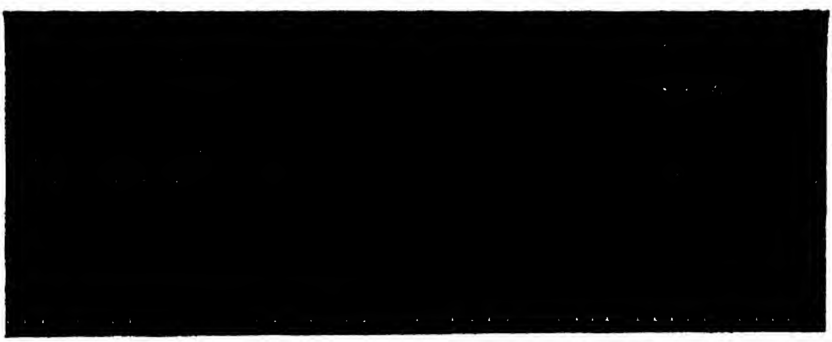

FIG. 476.—ARREST OF THE HEART BY IRRITATION OF THE VAGUS CAUSED BY AN ATTEMPT TO FARADIZE THE PHRENIC NERVE IN THE NECK.

of the heart. Although it is true that stimulation of the vagi cannot permanently arrest a healthy heart, vagal arrest of the heart, superimposed upon profound cardiac depression, may provide the finishing touch to the laboring organ (Figs. 476 and 477).

Should respiration cease under the effect of an anesthetic, artificial respiration should be at once performed. There are three methods by which considerable quantities of air may be made to pass in and out of the chest by the efforts of the operator. One of these is the so-called Sylvester method, in which the arms are drawn above the head after abduction and then adducted and laid across the chest with pressure upon the thorax. This is impracticable in most cases of anesthetic accident because of the narrowness of the operating table and the absolute flaccidity of the patient. The method advocated by Schäfer within the last few years, in which the patient is laid upon the anterior surface of the body with the head turned a little to one side, so as to avoid obstructing the mouth and nose, is also difficult of performance upon an operating-table. In this method pressure is exerted upon the

floating ribs, the heel of each hand being applied to the chest-wall at about the posterior axillary line, so that the lower segment of the chest is not only pressed upon from above, but compressed laterally. This method has the advantage that fluids, such as excessive secretion and vomitus, escape from the mouth and nose by gravity. The method which is most frequently employed, however, is that of Marshall Hall, which, although it possesses great disadvantages in that the volume of air which enters the chest is less than with the other methods, is more readily performed when the patient is lying upon an operating-table. In this method the patient, lying in the dorsal position, is treated by pressure exerted by the hands of the operator twelve times a minute upon the front and sides of the lower segment of the chest. The natural resiliency of the thorax draws air into the lungs when the pressure is removed. When this method is employed, it is necessary to see that the mouth and pharynx are free from secretion and fluid.

The Sylvester method is practically impossible on an ordinary operating-table.

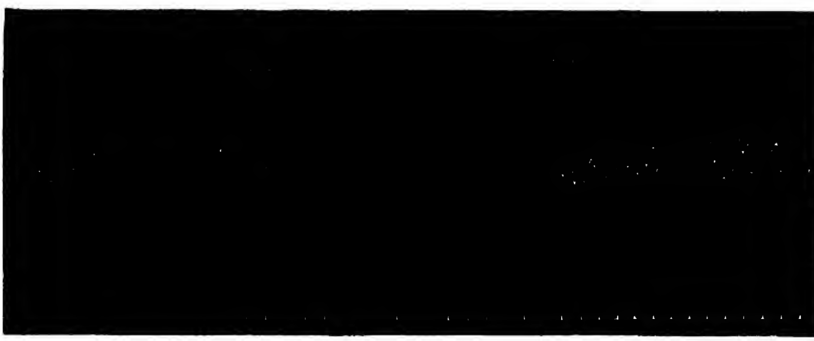

FIG. 477.—ANOTHER EXPERIMENT WITH THE SAME RESULT AS IN FIG. 476.

Laborde's method of artificial respiration is not so efficacious as the others, but can be used when the conditions prevent their employment in large, fat persons who are so chunky and heavy that artificial respiration, by compressing or moving the thorax, is impossible. It consists in seizing the tongue with forceps and drawing it fully out of the mouth with considerable traction fourteen times a minute. The effect produced is entirely reflex, since these movements cannot, of course, mechanically affect the chest-walls.

The posture of the head, when artificial respiration is being performed, is most important. Many years ago Howard, of London, showed that if the head is allowed to hang over the end of the operating-table, the epiglottis is completely removed from the glottis in such a way that the free passage of air is allowed. On the other hand, as has been pointed out by Dr. Martin and myself, this method of Howard causes the soft palate to be strapped over the root of the tongue in such a way that respiration must be carried on through the nasal passages, which is a great disadvantage in view of the fact that these passages

may be obstructed by secretion, by hypertrophied turbinated bodies, by adenoids, or by deformities. Dr. Martin and I proved that if the head is extended and shot forward, so that the occiput is raised from the

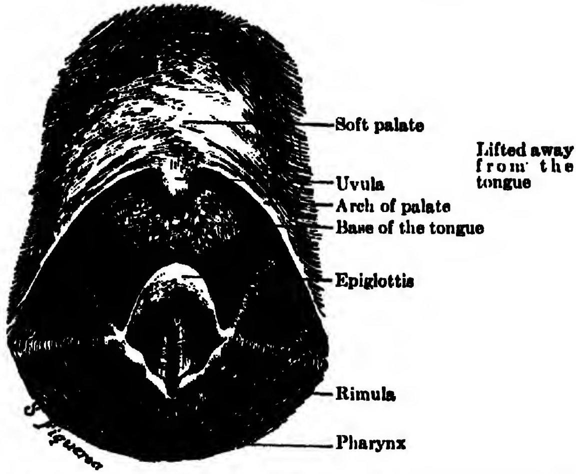

FIG. 478.—When the Neck is Stretched and the Head Pushed Forward the Epiglottis is Raised and the Soft Palate is Not Strapped over the Base of the Tongue. Nasal and Mouth Breathing are therefore Possible.

table 2 or 3 inches, the epiglottis is well removed from the glottic opening, and the soft palate does not compress the root of the tongue. This posture of the head permits free breathing through the mouth as

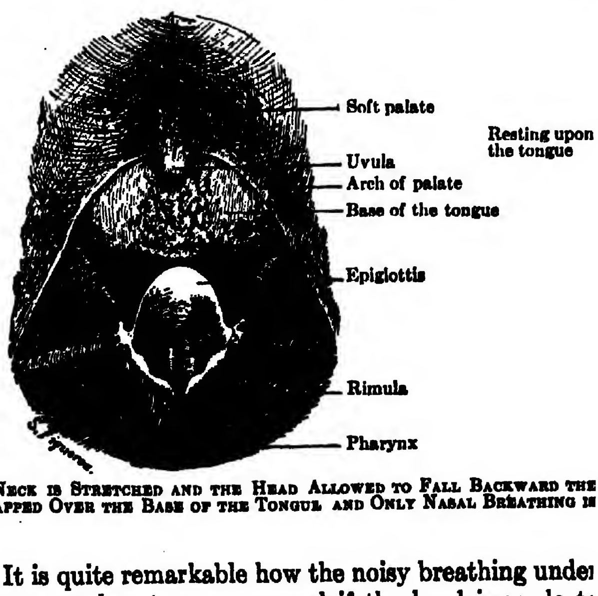

FIG. 479.—When the Neck is Stretched and the Head Allowed to Fall Backward the Soft Palate is Strapped Over the Base of the Tongue and Only Nasal Breathing is Possible.

well as the nose. It is quite remarkable how the noisy breathing under ether and chloroform can be at once removed if the head is made to assume this posture, a posture which can often be readily maintained

at least in part, by placing a tightly rolled towel upon the table, between the nape of the neck and the occiput. It is distinctly the most efficient posture for the head and neck when artificial respiration is to be performed (Figs. 478 and 479).

If care is taken that the anesthetic is not given too freely, thereby irritating the pharynx and larynx and relaxing the patient too greatly, and if the posture of the head just advocated be maintained, little trouble will be experienced in most cases because of stertorous breathing,

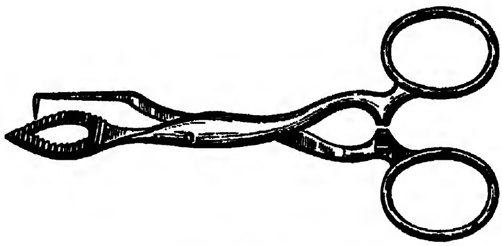

FIG. 480.—SENN'S TONGUE-HOLDING FORCEPS.

due to relaxation of the soft palate and falling back of the tongue. This falling back, or "swallowing of the tongue," is more prone to develop in old persons with relaxed cheeks and no teeth than in other individuals. If it occurs, and change of posture of the head does not relieve it, the tongue may be seized by the thumb and finger covered with a towel, and drawn forward, and if this measure fails, then tongue forceps should be used. Dr. George W. Spencer, of the Jefferson Hospital, who has had an experience of over 5000 cases, decidedly prefers the

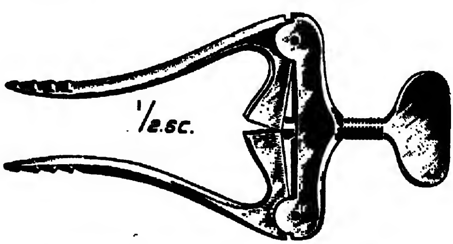

FIG. 481.—HEISTER'S MOUTH-OPENER.

forceps with a single tooth (Fig. 480) to the fenestrated forceps on account of the danger of destructive pressure upon the tissue of the tongue by the latter. Especially is this a danger in cases in which rhythmic traction upon the tongue is necessary. While it is true that the toothed forceps produces a punctured wound of the tongue, yet neither Keen nor Spencer has ever seen such a wound become infected. Care, however, must be taken with the toothed forceps, especially when rhythmic traction is required, lest the tongue be torn. Spencer strongly advises that the tongue should be seized by the toothed forceps, not vertically, as is usually done, but horizontally, *i. e.*, at the sides.

In addition to a pair of tongue forceps the anesthetizer should be provided with a mouth-opener, such as that of Heister (Fig. 481) or Buxton's ratchet gag (Fig. 482). These may be employed for the purpose of forcing apart the jaws when there is spasm of the masseter muscles, or for holding the jaws apart when such spasm is feared. Sometimes a wooden wedge can be used for the same purpose. (See Luke's book.)

To prevent irritation of the respiratory passages, Spencer uses a spray of menthol and camphor, 8 grains of each in an ounce of liquid albolene, which is very effective. He also prevents irritation of the conjunctivæ by frequently dropping into the eyes a warm solution of boric acid, 6 or 8 grains to the ounce.

When the circulation fails suddenly, or becomes feeble and the face is pallid, the patient will often be greatly benefited by the Trendelenburg posture, but this posture must not be used if the face is cyanosed, and with caution, if at all, in persons who have large bellies

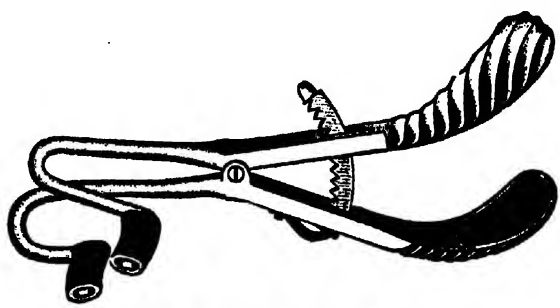

FIG. 482.—DUDLEY BUXTON'S RATCHET PATTERN GAG.

or in those who have had large bellies as the result of disease. In these persons the pressure of the abdominal contents upon the diaphragm seriously impedes respiration and the heart. When enlargement of the belly has pushed out the lower ribs, the withdrawal of a large growth or much fluid leaves the diaphragm relaxed, and I have seen death ensue after a large cyst of the ovary had been removed, because every inhalation drew the flabby diaphragm so high in the chest that sufficient air could not be inspired. In such cases bandaging the extremities must be resorted to, to confine the blood to the vital areas of the body.

Patients who have been deeply anesthetized for the performance of severe operations, particularly if the operation has been a long one, should not be placed in bed until they have begun to come out from the anesthetic, and should never be left alone until they have thoroughly recovered from the effects of the drug. During the period of returning consciousness the attendant should see to it that the patient does not draw into the deeper respiratory passages mucus and other secretions from the mouth and nose, or, after vomiting in the semi-anesthetic state, inhale materials which are brought up from the stomach. When coughing or vomiting occurs, such patients should be at once turned

on the side in such a way that free drainage from the mouth can take place.

When vomiting follows the use of an anesthetic with sufficient persistency to cause great discomfort or seriously to impair the patient's chances of recovery, several measures for relief may be resorted to. One of the simplest of these is the inhalation of vinegar fumes, the vinegar being poured upon a napkin and held over the patient's nose and mouth. How this remedy acts is not known. One of the most efficient internal remedies is acetanilid, given in 1- or 2-grain doses, every fifteen minutes or half-hour until 8 grains are taken. It may be dissolved in brandy, which is to be poured over shaved ice, and given in teaspoonful doses, or it may be placed as a dry powder on the tongue. In other cases similar doses of chloretone may be used, and if vomiting is incessant, so that the very attempt to swallow results in regurgitation, chloretone dissolved in brandy may be given in the corner of the mouth drop by drop, by means of a medicine-dropper, the medicament finding its way gradually into the stomach and anesthetizing the mucous membrane as it goes. Small doses of cocain, varying from $\frac{1}{4}$ to 1 grain, may be given in similar manner, but not more than 2 grains should be used in several hours lest it produce marked systemic effects. In other cases vomiting may be stopped by washing out the stomach by the use of a stomach-tube. Sometimes it may be necessary to give a rectal injection of 30 to 40 drops of deodorized tincture of opium with 60 grains of sodium bromid to quiet the vomiting center. If suppression of urine comes on, a hypodermic injection of nitroglycerin to relax spasm of the renal vessels, or the hypodermic use of 1 grain of spartein sulphate, may be efficacious in restoring the flow of this secretion, and the injection into the rectum of hot water, or even very cold water, may reflexly influence the renal vessels and so cause a flow of urine. In other instances two dry cups over each kidney are useful, or, in their place, a hot poultice may be placed under the loins.

Finally, it is important to remember that the skilful anesthetist is he who succeeds, by the administration of the drug in hand, in inducing surgical anesthesia and sufficient abolition of voluntary movement to permit the surgeon to operate without inconvenience, and yet does not overdrug his patient. Too often the desire to produce absolute quiet results in the patient's being saturated with the drug. This condition of saturation may seem to be advantageous during the operation, but the development of complications, which are frequently very serious, not seldom counterbalances any advantages primarily obtained.

CHLOROFORM.

Physiologic Action of Chloroform.—There is no drug or medicinal substance which has been so carefully and constantly studied by the bedside, the operating-table, and in the laboratory as has chloroform, and there is certainly no drug which during the last fifty years has given rise to more discussion. Indeed, it may be truthfully said

that no other subject in the realm of medicine has received such universal attention in every land, and by men in almost every department of medicine and surgery, not excluding the pathologist.

Chloroform acts upon all living protoplasm as a depressant or paralyzant, the difference in its action in various quantities, large or small, being a difference in degree and not in kind. Any apparent stimulant effect is in reality due to its primary irritant properties, and any increase in the rapidity or depth of the respiration and in the speed and vigor of the heart or rise in the blood-pressure being apparent and not real, or, if real, dependent upon the psychic effect of the drug or to the primary irritant effect of its vapor if it is used in concentrated form. Although clinically, and in the laboratory, many observers have reached conclusions that are at variance with some of the following statements, I nevertheless, believe, from a careful study of the literature and my own observations, that they give briefly the actual effect of the drug on the nervous, the respiratory, and circulatory systems of a healthy person.

Given by inhalation, *secundum artem*, chloroform, after a brief quickening of the pulse and respiration, causes a gradual decrease in the activity of the perceptive portions of the cerebrum, followed or accompanied by a similar obtunding of the intellectual activities (of the anterior—the frontal—convolutions), and, finally, if the dose be adequate, produces a similar state of quiescence of the motor portions of the cortex. It also depresses the sensory pathways in the spinal cord, and, if still further pushed, depresses the sensory portions of the medulla. If still further pushed, the motor portions of the cord and medulla are depressed, but when this effect has been produced, the drug has been used to a degree considerably in excess of the amount which should be employed for surgical anesthesia. A step more, and the vital functions which reside in these parts will be abated, and death will ensue. It is by its action upon the perceptive centers in the posterior convolutions that the chief anesthetic effect of the drug is produced, for, as already pointed out, it is possible by its use to cause diminished sensibility before cerebration, in the sense of thought, is ablated, and before voluntary movement is arrested. The exact change produced in the cells is generally believed to be a solution of their lipoid substance, which, however, is not removed from the cells, which return to their normal state as the effects of the drug cease.

Upon the respiratory and circulatory systems the action of the drug is forcible and important. There can be no doubt that the dominant effect of the drug upon the respiratory center is depressant, but this action is in part due to the alterations in the blood-supply of the medulla, and is not a factor of great importance as compared to its circulatory effect. In other words, the drug in any dose, within the limits of ordinary usage, does not cause death by direct depression of the respiratory center in a previously healthy person. The changes in the blood-supply of the medulla and the effect upon the mind of the patient may alter the rhythm and depth of the respiratory movements, and these are to be carefully watched, not because they directly presage

disaster, but because they afford an opportunity to determine the dose of chloroform being inhaled, the quantity on the inhaler not being a guage. In other words, the respiration is to be watched, because if deep, rapid, or stormy, a dose of the drug may be taken which will produce disaster to the circulation and indirectly to the respiration. Those who at the present day advocate watching the respiration rather than the pulse, do not do so because they believe that death is due to failure of the respiratory center, but because they regard this function as a delicate indicator of good or evil progress.

In all cases, watching the respiration is more important than watching the pulse, because by this means we estimate the dose, and we estimate how much the respiratory center is suffering from a failing circulation, whereas when the pulse flags or stops, the danger is so imminent that it may not be put aside. If possible, watch both functions, but if not both, then watch the breathing.

When we come to discuss the effects of chloroform on the circulation itself, we meet with the chief fields of physiologic debate. There can be no doubt whatever that chloroform in any dose diminishes cardiac power rather than increases it, but there can also be no doubt whatever that when given to a healthy man the depression of the heart muscle is not the chief primary effect on the circulation. The primary and chief effect is upon the vasomotor center, and possibly upon the muscular coats of the vessels, and, as a result, chloroform always causes a fall of blood-pressure from the very first moment of its use after the nervous apprehension of the patient ceases. The work of Bowditch and Minot (Boston Medical and Surgical Journal, 1874), of myself and Thornton (Therapeutic Gazette, February, 1893), and of the two Hyderabad Chloroform Commissions (Bombay, 1888 and 1890, also London Lancet, January 18, 1890, prove this beyond all doubt, and every research that we have studied shows the truth of this assertion, namely, that a fall of blood-pressure occurs.

This fall of blood-pressure is not alone due to depression of the vasomotor center, but in part to the dilatation and diminished power of the heart, which in consequence drives the blood with less power and in less quantity a minute into the arteries. As the pressure falls the blood-supply to the medulla and the respiratory center is decreased, and the functional activity of these parts is diminished, partly by the direct and partly by the indirect effect of the drug. Aside from the experimental evidence of this fact, the whole history of the methods of restoration in chloroform accidents reveals that the object aimed at is an increase in the supply of blood to the medulla. The inversion of the patient, the application of bandages to the limbs, the employment of atropin to prevent or relieve "bleeding into the vessels" of the splanchnic area, are all efficacious, because they supply the medulla with blood, and they would be futile if the impending death were due to cardiac failure or arrest. Incidentally, of course, the restoration of medullary activity and arterial pressure supplies the coronary vessels with more blood, and so the heart is bettered. The use of pressure

on the abdominal aorta, as devised by Leonard Hill, whereby the circulation is chiefly confined to the upper segment of the trunk and the arms, is efficacious for this reason. On one occasion, when I was giving chloroform for a colleague who was doing an abdominal section, the face became ghastly white, the pulse was lost, and the heart-sounds were inaudible, yet instant recovery ensued when, at my request, he grasped the aorta through the abdominal wound and so restored blood-pressure in the cerebral vessels and heart. If the heart had stopped, such a measure would have been fruitless. When the additional fact is recalled that very many of the accidents from chloroform have occurred when the patient was sitting in a dentist's chair and not reclining, this state of vascular relaxation becomes still more evident.

To sum up, therefore, chloroform may be said to act primarily upon the vasomotor center, secondarily upon the respiratory center, directly and indirectly, and, lastly, upon the heart. Of course, any sharp dividing line between these effects is impossible, and all are depressed simultaneously, the difference being in degree. The statements just made do not in any way whatever deny that chloroform may cause death by sudden cardiac failure, the arrest of the heart in such a case being the dominant effect of the drug, because what holds true of a man in health does not hold true of a man who is diseased. In a man who has a degenerated myocardium, in which the remaining functionating fibers are staggering under the load caused by an abnormally high tension due to arteriocapillary fibrosis, all the factors are present, whereby a cardiac death is produced.

We come then to the important question of the influence of chloroform in producing cardiac arrest through irritation of the vagus nerves, the reflex starting through the trigeminus or the laryngeal nerves. Although it is impossible to arrest the heart permanently in a healthy person by increasing vagal activity, this influence, in a case of myocardial disease, or when the heart is depressed by chloroform, may be the last straw to turn the balance.

Chloroform exercises no direct effect on the blood. The drug is carried by the corpuscles, not the plasma, except to a very slight extent. Buckmaster and Gardner (Proceedings Royal Society, 1906, lxxviii., 414; 1907, lxxix., 309; 1907, lxxix., 555, 566) have shown that the concentration of chloroform in the blood for anesthesia is 14 to 27 milligrams to 100 grams of blood, and that 40 milligrams to 100 grams causes death. Tissot (Revue Scientifique, vol. v., and Lancet, 1908, ii., 1232), on the other hand, places the lethal dose of chloroform at from 60 to 70 milligrams per 100 grams of blood.

The effects of chloroform or of any other anesthetic, for that matter, do not depend upon the quantity placed upon the inhaler nor the quantity taken into the lungs, but upon the amount which is absorbed from the lungs by the blood, and again upon the amount which is absorbed by the tissues from the blood, and particularly those tissues of the nervous system which are closely associated with vital function.

Tissot has shown that when chloroform narcosis is developed slowly, that is, in from ten to twelve minutes, anesthesia is effected by from 32 to 38 milligrams in 100 grams of blood. In more rapid narcosis the amount is from 50 to 70 milligrams in 100 grams, and in medium cases, taking from four to six minutes for the development of chloroform anesthesia, 42 to 46 milligrams to each 100 grams are present. Tissot, however much his results as to exact percentages may differ from some other investigators, as, for example, Buckmaster and Gardner, nevertheless is in accord with them to the effect that the lethal dose of chloroform in the blood is double the anesthetic dose. It would seem probable that the accumulation of chloroform in the tissues depends to a certain extent upon their activity and the activity of their blood-supply. Where the circulation is free and the chloroform is deported from the tissues almost as rapidly as it is imported, the danger is much less than if the circulation is impeded, since, under these circumstances, the importation is more rapid than the deportation. This is probably one of the reasons why asphyxia, which always results in venous congestion, and struggling on the part of the patient, which produces a similar effect, is so prone to be accompanied by chloroform accident. It would also seem probable that the longer chloroform is administered, the greater the quantity accumulates in the tissues. This is manifest from the clinical observation that patients who have inhaled chloroform during a long operation exhale this drug on the breath for many hours after the anesthetic has been discontinued; whereas this does not occur if the use of the anesthetic has been brief. The very presence of chloroform on the breath one or two days after the operation shows that it must have been stored in the tissues. This storage of chloroform in the tissues also explains why it is that delayed chloroform poisoning develops after prolonged operations more frequently than after short ones. All these facts serve to emphasize the necessity of administering chloroform slowly and deliberately. (See Untoward Effects of Chloroform, *infra.*)

Chloroform is rapidly eliminated by the lungs, and if given freely, by the kidneys, which it may irritate, but not sufficiently, if they are healthy, for this effect to be given serious consideration. (See Effects of Chloroform during its Clinical Use.)

The pupils are slightly dilated under chloroform. If they go into wide dilatation, this is an alarming sign, as it often shows relaxation of the sphincter muscles, which is associated with impending death.

The Administration of Chloroform.—Chloroform should never be used as a surgical anesthetic unless it is capable of responding to the following tests: Its specific gravity at 17° C. should be 1.491 to 1.500. Its boiling-point, 60.16° C. (140.2° F.). It must be perfectly transparent and without color, and absolutely neutral to test-paper. Its vapor should not be irritating, and when poured over the hand or upon a watch-glass it should leave no odor after it has evaporated, nor any residue in the glass. If shaken with strong sulphuric acid, not more than the faintest trace of a brown discoloration should appear, and no

precipitate should be formed when it is mixed with a solution of silver nitrate. Added to caustic potash and heated to the boiling-point, a brown color should not appear.

Chloroform should never be used near the flame of a gas-jet or coal-oil lamp, since under these circumstances the chloroform vapor is decomposed, with the production of exceedingly irritating fumes, composed principally of hydrochloric acid and chlorin, which may cause an intense irritation in the respiratory passages of the surgeon, the patient, and the anesthetizer. When it is necessary to operate under chloroform and in the presence of a near by gas-flame, the irritant fumes can, to a certain extent, be neutralized by hanging in the room towels wet with ammonia water.

When chloroform is administered by inhalation in proper quantities, the respiratory passages are not irritated by its vapor, the patient gradually becomes stupefied, and then often, with great rapidity, passes from the condition of consciousness to one of unconsciousness, only a few seconds elapsing between one state and the development of the other. Because of the profound dilatation of the splanchnic vessels, the skin is usually pallid under chloroform.

In the administration of chloroform it is of vital importance that there shall be a free supply of fresh air, not alone to the room in which the drug is given, but the air must have free access to the patient's lungs. One of the reasons why the percentage of deaths from chloroform is less in warm countries, as, for example, in India, than in cold, is that the operations in the tropics are performed practically in the open air, whereas the atmosphere of the operating-room in the temperate zone, at least in the winter months, is often so stifling that it oppresses the spectators, although the attendants and the surgeon may not notice it because of their interest in the operation.

A common method of giving chloroform in America consists in dropping the drug on a folded napkin, which is then held over, not in contact with, the patient's nose and mouth, the patient's head being as low as the trunk. Another method, better than this, is the use of the wire mask, called the Esmarch or Schimmelbusch Inhaler. Over this mask is stretched a single thickness of thin flannel, and upon this flannel the chloroform is allowed to fall, drop by drop, no attempt being made to saturate its entire surface. It has been shown that the texture of this piece of flannel, or of other cloth, greatly influences the dose of chloroform actually received by the patient, since a wide mesh permits the rapid diffusion of the chloroform, and the air is drawn so readily through the fabric that it takes with it a large amount of chloroform vapor.

For many years English surgeons have resorted to the use of cumbersome and complicated apparatus for the administration of those drugs which are employed to produce anesthesia by inhalation. It is always wise to use the simplest apparatus possible in the performance of any mechanic or other act requiring extraneous aid, and this rule certainly applies in regard to the administration of these pain-relieving agents.

The ordinary folded napkin or towel, or the exceedingly simple inhaler of Esmarch, is without doubt the best thing which can be used for the administration of chloroform. If, however, it is considered desirable to use a mechanic inhaler, the instruments of Junker or Skinner (Figs. 483 and 484) may be employed.

There are three cardinal rules in the use of chloroform for the production of anesthesia, namely: give a plentiful supply of atmospheric air and only enough chloroform to put the patient gently to sleep. If the respirations become stormy or their rhythm is greatly disturbed, the drug should be withdrawn until they are normal, and, lastly, if the patient struggles, no chloroform should be given until the struggles cease. The free use of the drug to overcome struggling has frequently caused death, because the heart is strained and depressed by the muscular efforts, by the chloroform and the CO_2 in the blood, and the dose inhaled is unknown and beyond control. Hewitt, Lawrie, and many others very properly insist that when chloroform is given, its dose should be so nicely adjusted that a trace of the corneal reflex is retained.

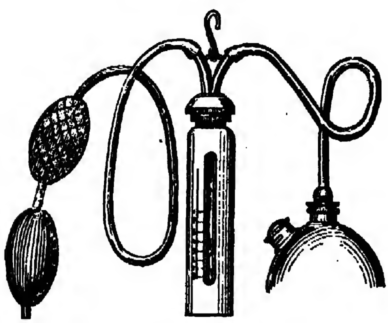

FIG. 483.—JUNKER'S INHALER FOR ADMINISTERING CHLOROFORM.

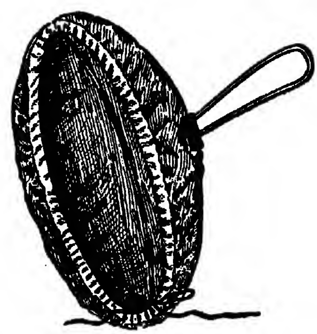

FIG. 484.—SKINNER'S MASK FOR ADMINISTRATION OF CHLOROFORM.

The skilful anesthetist, by the exercise of judgment, can vary the quantity of the anesthetic according to the needs of the patient at different periods during the operation. At times, when the surgeon is not dealing with sensitive tissues, the patients may be kept upon the borderland of anesthesia. A few moments later it may be advantageous for the time being to push the anesthetic in order to overcome necessarily painful procedures. Thus, it is well known that when the first incision is made into the abdominal wall, death frequently occurs. In nephrectomy, when the pedicle is being pulled down, dangerous symptoms sometimes arise, and this also occurs in hysterectomy, when the greatest traction is being made upon the organs. There is some difference of opinion, however, in regard to the value of increasing the effects of the anesthetic at these critical moments. While many surgeons and anesthetists think it advisable, no less an authority than Hewitt believes that the pushing of the anesthetic at this time may add the shock of the anesthetic to the shock of the operation, and, therefore, increase the danger rather than diminish it.

If shock is already present, chloroform is a more dangerous drug than ether, and the greater the shock, the lighter should be the anesthesia developed by the use of either of these drugs. There can be no doubt that the greater amount of shock occurring during the administration of an anesthetic occurs in abdominal, thoracic, and cerebral operations, and also those upon the testicle and kidneys.

Untoward Effects of Accidents Due to Chloroform.—The most common accident under chloroform is sudden circulatory failure. This is to be prevented, in cases in which the state of the patient before operation leads one to fear trouble, by the hypodermic injection of $\frac{1}{100}$ grain atropin, which has been proved experimentally and clinically very actively to prevent sudden circulatory collapse, chiefly by raising blood-pressure in the splanchnic vessels, and to a less extent by diminishing the irritability of the vagus. Another preventive measure is the application, to the limbs, of tightly fitting elastic or flannel bandages, so as to confine the circulation largely to the trunk. Upon the onset of definite signs of circulatory failure the patient should be inverted by having the legs hang over the surgeon's shoulders while the head rests upon the floor. An assistant should give $\frac{1}{50}$ grain atropin with $\frac{1}{10}$ grain strychnin hypodermically into the pectoral muscle, because absorption is quicker from a muscle than from the subcutaneous tissues, and because the circulation in the limbs is so poor that absorption will not occur promptly from these areas. The reflex effect of giving the injection into the chest-wall is also advantageous. This advice, at least so far as the use of strychnin is concerned, is given advisedly, notwithstanding the statement made by some persons that, as the vasomotor center is paralyzed, strychnin can do no good. In the first place it is not paralyzed, but only depressed, and this being the case, strychnin can wake it up. In the second place, excellent experimental work has proved that strychnin will aid resuscitation, and, in the third place, that most excellent physiologist, Townsend Porter (Amer. Jour. Physiol., December 2, 1907), of Harvard, has shown that the operative procedure does not, in all probability, lower pressure by paralyzing the vasomotor center by shock. Strychnin has been greatly abused by surgeons in operative shock, but it is now unreasonably banished from the operating-room by many operators.

The inhalation of amyl nitrite in this state is based upon an utterly erroneous idea of its effects. It still further increases vascular relaxation and decreases the motor activities engaged in respiration, a function which should be as active as possible to help eliminate chloroform from the lungs. There can be no doubt that active artificial respiration is, for this reason, advantageous, and it possesses the additional advantage that the application of pressure by the hands upon the thorax aids directly or indirectly in relieving the engorged cardiac cavities. If the belly is open, the engorged heart may be started again by unloading its cavities through gently manipulating this viscus through the diaphragm.

As soon as possible, adrenalin chlorid, in the proportion of 1 dram of

the 1:1000 solution to 1 pint of hot normal saline, should be given intravenously. Under these circumstances the adrenalin is carried promptly to the heart, which it stimulates, and then is distributed by the blood-stream to the arterioles, which it contracts, and thereby raises blood-pressure. Crile has advised its use intra-arterially against the direction of the blood-flow. This may be advantageous if arterial circulation has ceased and venous stasis is absolute, but if the circulation has not ceased—and it has not in most humans who can be resuscitated—an intra-arterial injection must fail, since the adrenalin-saline solution will not go against the blood unless the force used in the injecting is very great, and if it be great, the work of the heart is increased. Even if a high pressure is used, the drug cannot reach the heart through an artery while the blood is still flowing, unless a great cervical vessel is used. Furthermore, the value of the adrenalin is due to its effects upon the muscular fibers of the arterioles, as it does not act upon the vasomotor center. The sooner it goes to the arterioles, therefore, the better.

The intravenous injection of normal salt solution for the purpose of directly raising blood-pressure in chloroform collapse is futile, because many times the total quantity of the blood can be injected without raising arterial tension. Indeed, before the pressure rises the patient is drowned by extravasation into his tissues. Further, the injection of a great bulk of saline only increases the labor required of the distended and enfeebled heart.

Another useful method in combating shock or collapse during the administration of an anesthetic is to give, by the rectum, from a pint to a quart of hot normal saline solution or an equal quantity of strong coffee. Such an injection does good not only by its absorption and by its heat, but also by the reflex effect which it produces upon the blood-vessels of the abdominal viscera.

In addition to applying bandages to the extremities in feeble patients to whom chloroform has to be given, it is often wise to place the body in the Trendelenburg position, since by this means the circulation at the base of the brain is more readily maintained.

Within the last few years the development of post-anesthetic chloroform illness and death has received wide attention, particularly careful studies having been made by Bevan and Favill in America, Guthrie in England, and a number of others. (See Bibliography.) It has been proved to be a state closely allied symptomatically and pathologically to diabetic coma, and is a form of acidosis. It is particularly prone to develop in diabetics and in persons who are unduly fat, or those suffering from prolonged suppuration or other debilitating maladies.

The symptoms of so-called delayed chloroform poisoning appear at various intervals after the patient has apparently recovered from the shock of the operation and the use of the anesthetic. They may begin with the vomiting of foul, watery-looking fluid, sometimes resembling the dregs of beef-tea. The vomiting is accompanied by

extreme restlessness and an active delirium, which often changes to a state of apathy, which, in turn, more or less speedily deepens into coma. Jaundice and albuminuria soon develop, but death may not come on for four or five days, or even longer than this. Such symptoms usually do not develop before the twelfth or later than the forty-second hour after the anesthetic has been taken. The breath of these patients often has the odor of acetone, and diacetic acid and acetone are found in the urine. That symptoms of acid intoxication are not so rare as some persons have thought is shown by the fact that J. A. Kelly, in 400 cases collected in the Children's Hospital of Boston and the Boston City Hospital, found 46 which showed signs of acid intoxication, and of the 46, 6 died. The lesions found at autopsy in these cases consist in fatty changes in the liver resembling those characteristic of acute yellow atrophy, fatty changes in the kidneys, the suprarenal bodies, and in the epithelium lining the stomach.

In order to avoid delayed chloroform poisoning the drug should not be used in patients suffering from diabetes, prolonged suppuration, and hepatic cirrhosis. It should also be avoided in children of the large, lymphatic type. Malnutrition and starvation, which are, after all, nearly related states, also predispose to the development of chloroform poisoning, and, therefore, when chloroform is given, there can be no doubt that the preliminary diet of the patient should be carefully regulated, since much can be accomplished by this means in preventing acidosis. (See Preparation of the Patient for Anesthesia.)

ETHER.

Physiologic Action.—When ether is locally applied to a mucous membrane, it acts as an intense irritant, whether it be in the form of liquid or vapor. When inhaled or swallowed it is eliminated chiefly by the lungs, and in small part by the kidneys. It escapes from the body unchanged. It exercises its dominant influence upon the cerebrum. Primarily, it benumbs sensation by depressing the perceptive centers in the posterior convolutions of the brain; secondarily, it depresses the intellectual centers, and finally it depresses the motor cortex. Upon the spinal cord its influence is exerted upon the sensory tracts. If given in overdose, it acts as a depressant to the sensory portions, and then to the motor centers of the medulla. Neither the motor nor sensory nerves are affected by any dose which is ever employed for therapeutic purposes. When taken internally, or when inhaled in the form of vapor, ether causes a rise of arterial pressure by stimulating the vasomotor center and also by stimulating the heart. In moderate amounts there is an increase in pulse force and in pulse frequency, because of its stimulant effect upon the heart muscle. When large doses are given, ether is, however, capable of acting as a cardiac depressant. Upon the blood it produces no direct effect so far as our present knowledge extends. If given in poisonous amounts, it causes death by failure of the respiratory center. The heart is also depressed partly from the drug and partly from the accumulation of CO_2.

The Administration of Ether.—When ether is used in the presence of naked light or fire, the distance between the two must always be at least eight feet. It should also be recalled that, as *ether vapor is heavier than the atmospheric air*, it falls to the floor and is present there in far more concentrated form than the anesthetizer appreciates, and, being carried by draughts to a fire in an open grate, may cause an explosion, in which the flame may leap to the inhaler and perhaps seriously burn the anesthetist and the patient. A number of cases of this character have been reported, and Mr. Shield states that he has known the breath of a patient under ether to become ignited by a lamp held near by. Instances are also reported in which the use of a cautery in the neighborhood of the face has resulted in ignition of the vapor.

When ether is given by inhalation, the fact that its vapor is heavier than the atmospheric air must never be forgotten, since it passes from the inhaler to the respiratory passages of the patient in far more concentrated form than it passes to the face of the anesthetizer, whose nose and mouth are above the inhaler. It is for this reason that, during the first few moments of the administration of this drug, patients so often manifest restlessness and complain of a sense of oppression, and state that the drug is being pushed too rapidly. During the first few moments of the administration of ether, therefore, the inhaler should be brought very gradually toward the face in such a way that the patient's sensibilities are benumbed before concentrated vapor is actually inhaled. As the effects of the drug become manifest there is often some quivering of the eyelids and shallow breathing, alternated with deep inspirations; the face becomes flushed, the pupils dilated, the pulse is quickened, and occasionally the patient holds the breath for a number of seconds; indeed, it may be held for so long a time as to cause anxiety on the part of a novice. It is during this stage that the greatest consideration should be shown to the patient's sensibilities, and an encouraging word will often be of material aid in making the first stage quiet and devoid of complication. As the effect of the drug gradually increases a certain amount of muscular rigidity often develops, and hallucinations are often present, so that the patient thinks he hears various noises which in reality do not exist. At this time the patient may become more or less restless and even violent, and if the second stage is delayed in its full development, he may act as one intoxicated by alcohol—laughing, swearing, talking, or struggling. It is in alcoholic patients that these manifestations are chiefly met with, and they appear more commonly in men than in women. It is a noteworthy fact that women of the better classes usually take ether very quietly if they have confidence in the anesthetizer and are moderately encouraged, whereas women of the lower type are often exceedingly noisy, struggling violently. Owing to these hallucinations, no anesthetic—and this is especially true of ether—should ever be given by the surgeon alone. The patient may attack the surgeon in the belief that he is an enemy, and may do him serious bodily harm. In the case of women, this precaution is especially needful, lest they become the victims of a fixed hallucination that the

surgeon has attempted to assault them, and even bring suit against him.

If the ether is pushed in moderate quantity, as it should be, the state of full anesthesia is soon developed. Under these circumstances there is loss of the reflex action, unconsciousness, and muscular quiet, voluntary motion being almost entirely lost. The pulse is full and strong, and usually somewhat quickened. At first the arterial pressure is raised, but if the etherization is continued for a long period, is eventually lowered. As ether raises blood-pressure and does not dilate the splanchnic vessels, the skin is often flushed during the whole time that the drug is skilfully administered. The respirations are usually a little deeper than normal. The temperature is constant if the anesthesia is brief, but if prolonged, it falls rapidly, a drop of as much as from 1 to 3 degrees often taking place. In those instances, however, in which a fall of 3 degrees takes place, the shock of the operation is probably the chief cause of the fall in body heat. Even if ether is given skilfully, there is often such distinct flushing of the face that slight cyanosis may be present. If the respiratory passages become choked with secretion, and if the patient is deprived of an adequate quantity of atmospheric air, distinct cyanosis often appears, but it usually speedily disappears if the ether is stopped for a few moments. If a great amount of mucous accumulates in the air-passages, the head-down posture will often relieve, or in the case of children, they may be held up by the heels for a few moments. The mucus may escape even in a copious stream. Beyond this stage of surgical anesthesia the effects of ether should never be pushed, since the development of its effects to a further degree will be followed by total muscular relaxation, which will involve the diaphragm, and so seriously impair respiration, the drug under these circumstances also acting as a depressant rather than as a stimulant to the respiratory center. The skin becomes cold and pallid, the pupils dilated, the pulse fluttering, and a cold sweat may come on.

As the effects of ether, when used for the production of surgical anesthesia, pass off, the patient is often restless, rarely violent, but sometimes noisy, and often lachrymose, any pain which is present being oftentimes exaggerated, self-control being impaired by the drug. Vomiting is by no means unusual. It is nearly always present if ether has been given too freely. The vomitus also strongly smells of ether, which is probably due to some of this drug being swallowed in the freely secreted saliva and mucus. Dizziness and vertigo may also be present. (See Care of Patient During and After Anesthesia.)

Recognizing the fact that far too much ether was administered to the vast majority of patients, Dr. Allis, of Philadelphia, many years ago invented what is known as "Allis's inhaler" (Figs. 485 and 486), which has been used very largely in this country because it provides the patient with a large amount of atmospheric air at the same time that it permits the anesthetist to administer adequate quantities of ether vapor, with the result that the old ether cone, made out of a towel and supported with felt or pasteboard in such a way as to make

it impervious to air, has almost entirely disappeared from use—to such an extent that the modern trained nurse does not know how to make the ether cone which her predecessor so dexterously prepared twenty years ago.

More recently the so-called drop method of administering ether has come into vogue, as surgeons and others have recognized more and more clearly the fact that most of the evil sequences to ether anesthesia are due to the fact that the patient has received an excessive quantity of ether vapor. Whenever this so-called drop method has been used, a remarkable diminution in evidences of pulmonary and renal irritation and gastric disorder has taken place, so that with the best operators the drop method of using ether is now universally employed, with the result that the patient is no longer saturated with the drug and no longer exhales ether in his breath for several days after the operation. It is quite true that this method may involve the loss of a greater quantity of ether than the older closed method, for as the ether is dropped upon

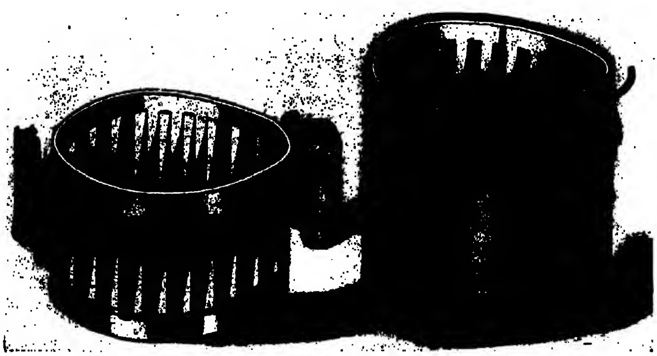

Fig. 485. Fig. 486.

Figs. 485 and 486.—Allis's Ether Inhaler. (Fowler.)
Showing fenestrated metallic frame with a muslin roller in course of application, and the inhaler complete with cover.

a folded towel, as is chloroform, a considerable quantity escapes into the surrounding air. On the other hand, when it is remembered that ether vapor is heavier than the atmosphere, it is also recalled that if the napkin upon which the ether is dropped is held immediately above the face of the reclining patient, the vapor of the ether passes to the nose and mouth in an invisible cloud in quite as great a concentration as is necessary, and, unless the ether is poured on the napkin very lavishly, but a comparatively small quantity is lost. Indeed, it is probable that, with the old method, in which the ether was soused upon the cone, a greater quantity was wasted than by the more modern plan. When, however, it is considered desirable to use some mechanic device for the administration of ether, the following inhalers may be resorted to.

In using Clover's ether inhaler (Fig. 487) the following rules must be adhered to. Place the indicator at "1" or "2" for the escape of air. Then pour in 1½ ounces of ether, put the plug in place, and set the indi-

cator at zero. The bag is then attached, and the patient directed to breathe through the mouth. While he is doing this the inhaler is applied to the face, using a little more pressure during expiration than during inspiration, in order that the bag may become inflated with the expired air.

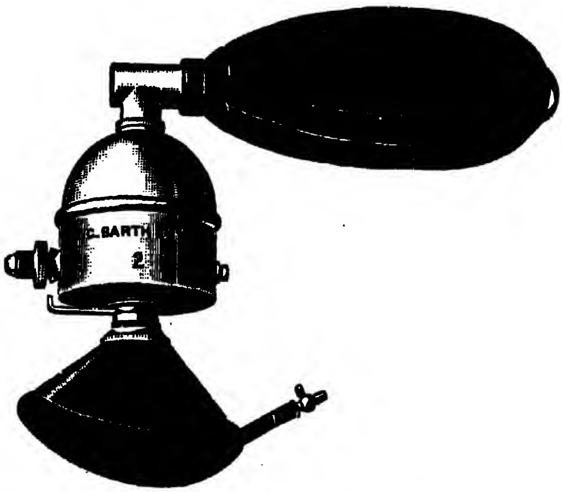

FIG. 487.—CLOVER'S ETHER INHALER.

This condition is maintained for about thirty seconds, a period which is utilized by the anesthetizer to determine that the bag inflates and deflates rapidly. The indicator is now gradually rotated, so that, by the expiration of the first minute, it points to "1," after the second minute to "2," and after the third, to "3." The indicator should not be moved suddenly, but very gradually. Unconsciousness usually comes on in from one to two minutes, and as it develops the ether may be admitted more and more freely. If the patient holds the breath or coughs, it is a sign that the vapor is being given in too concentrated a form, and the indicator must be adjusted so as to diminish it. If the patient struggles or excitement is manifested, the indicator should be moved so that the ether will be given in more concentrated vapor. If the weather is cold or the patient is a powerfully built man or an alcoholic, it is usually wise to dip the ether reservoir in warm water for a few

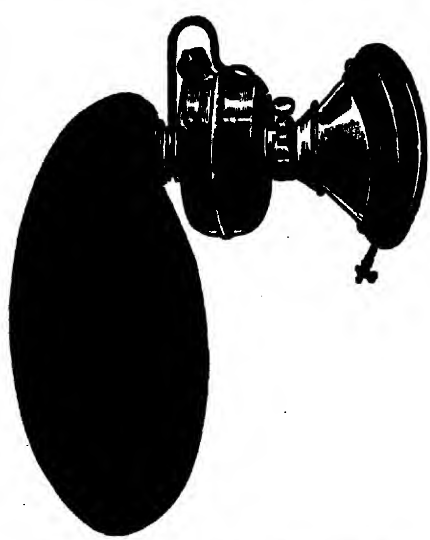

FIG. 488.—HEWITT'S WIDE-BORE INHALER.

moments before it is used, in order to aid in the rapid vaporization of the drug. If the breathing becomes stertorous, one or two breaths of fresh air may be allowed by lifting the face-piece, and when the stertor ceases, it may be again applied closely, but, as a rule, the patient does best if a considerable quantity of air is admitted, as by this means too deep an anesthesia is avoided. Hewitt advises, for the first four or five minutes, one inspiration of fresh air, after from ten to twelve breaths, and if the drug is continued for more than a half-hour, that one inspiration of fresh air be allowed every four or five breaths. If cyanosis becomes marked or respiration labored, still more air is required. Hewitt also points out that what might be called the toxemic factor is almost as powerful as the ether factor in this system of ether anesthetization, and this is, as we have already pointed out, the chief objection to the use of this method; the patient ought to be slowly anesthetized by ether, and not by ether and carbonic oxid. After the anesthesia has been continued for fifteen minutes to half an hour, the indicator is placed at "2," or even at "1½," which will provide enough of the drug

FIG. 489.—ORMSBY'S INHALER. (Fowler.)

A, Rubber bag; B, sponge; C, adjustable cap for regulating the admission of air; D, tube for conducting air above the sponge; E, metal face-piece with wire cage for sponge; F, inflatable cushion for face-piece.

to maintain anesthesia. The more powerful the patient, the less air will be needed. On the other hand, if the patient is a child or a feeble adult, more air will be required.

If ether is given by Braine's modification of the Ormsby inhaler (Fig. 489), a sponge with wide meshes and sufficiently large practically to fill the cage is placed in this container, and a small quantity of ether is poured upon it. The air-slot is left open, and then the mask applied to the face—not too closely, the patient being instructed to breathe freely. The air-slot is then gradually closed, and the patient now receives practically only ether vapor and the expired air which has inflated the bag. If more ether is required, about ½ ounce is again poured upon the sponge.

Another method is to place a dry sponge in the cage after pouring ether into the bag. The face mask is lightly applied, and the ether in the bag is shaken so as to distribute it over its surface. Then, as the patient gradually passes under the anesthetic, the bag is tipped until the ether runs out and wets the sponge. After this, if more ether is required, it may be poured directly on the sponge.

THE USE OF OXYGEN WITH CHLOROFORM OR ETHER.

About fifteen years ago the administration of oxygen gas mixed with chloroform or ether vapor, and even with nitrous oxid, became exceedingly popular with surgeons, it being claimed that by its use many of the disagreeable symptoms produced by the administration of any of these anesthetics could be avoided. Cyanosis was thought to develop with less frequency, and vomiting, both during and after the operation, was said to be diminished in frequency and severity. Long experience, however, has resulted in the opinion that the use of oxygen with anesthetics is not so valuable as it was once thought to be. Its fall from its high estate in the minds of surgeons has probably been due, in large part, to its faulty administration. There can be no objection to its employment if it is used properly, since it is incapable of doing harm and it may do good. To administer the oxygen with the vapor of the anesthetic by causing the gas to bubble through the liquid anesthetic contained in a wash-bottle is a distinctly faulty method. In the first place, there is a possibility of the oxygen gas causing a chemic change in the ether or the chloroform, and, in the second place, it is impossible, under these circumstances, to increase the oxygen without increasing the quantity of the anesthetic, or to increase the anesthetic without increasing the quantity of the oxygen. It is a well-known fact to physiologists that, if artificial respiration is performed with great activity, a condition of apnea develops by reason of the fact that the respiratory center no longer sends out impulses. When, therefore, the patient breathes almost pure oxygen gas and anesthetic vapor, a condition of apnea is soon developed, and, as the activity of the respiratory center diminishes, smaller quantities of the anesthetic are inhaled, with the result that the patient passes under the anesthetic very slowly, if at all. The more gas is given the less anesthetic is taken, because of the shallow respirations; whereas, if the supply of gas is cut down and it does not bubble so freely through the anesthetic, less of the anesthetic passes to the respiratory passages of the patient, and so anesthesia is slowly produced, if at all. The proper method to be employed in the use of oxygen with an anesthetic is to keep the gas and the vapor separate until the moment of inspiration, carrying the nozzle on the end of the rubber tube leading from the oxygen tank under the edge of the inhaler in such a way that the gas is delivered at the corner of the mouth or by the nostrils. The anesthetic can then be given by any means the surgeon approves, and the anesthetizer has complete control of both factors. He can diminish one and increase the other, as may be required, giving pure oxygen, oxygen mixed with air with no anesthetic, or the anesthetic without oxygen, as he chooses.

The use of oxygen and one of the anesthetic vapors by means of one of the inclosed inhalers, whereby air is largely, if not altogether, excluded, is particularly disadvantageous. As human beings are meant to breathe atmospheric air and not oxygen alone, it is much better that they should have an adequate supply of air than that they should be forced to live

on oxygen, although it is conceivable that advantages may accrue by the administration of additional oxygen over and above that contained in the atmosphere.

That form of closed inhaler fitted with valves and with a large rubber bladder which the patient inflates or deflates in each respiratory cycle is to be strongly condemned. It would be hard to devise an apparatus open to greater objections. By its use the patient repeatedly breathes anesthetic vapor and CO_2, which has been exhaled from his lungs, with all the other products of expiration. Into this bag are also driven, by coughing and stormy breathing, particles of saliva containing septic organisms, which, on being drawn into the chest on inspiration, pass nature's barriers and gain access to the deeper portions of the lungs.

NITROUS OXID.

Physiologic Action.—Nitrous oxid produces anesthesia by its direct physiologic effects and not by causing asphyxia, although at one time its ability to relieve pain was supposed to be due to such an influence. It does, however, produce asphyxia when it is taken without being mixed wtih oxygen or atmospheric air. When inhaled, the gas is dissolved in the blood, but does not form a new chemic compound with the hemoglobin, neither is it decomposed in the body. If its administration is continued for a long period of time and no air is allowed to reach the patient's lungs, death takes place partly from its direct depressant effect on the respiratory center, but chiefly because of lack of oxygen. When inhaled for medicinal purposes, it causes a rise in blood-pressure and a slowing of the pulse, which effects are chiefly due to the asphyxia. The heart is not affected to any extent by the direct action of the drug, but the function of this viscus may be impaired if the gas is continued for a long period of time, because of the lack of oxygen. The hemoglobin of the blood is not changed, save that the amount of reduced hemoglobin always present in asphyxia is increased. As the drug does not possess any irritant properties, and as its influence upon the lungs and heart is so slight as to be of little importance, it is an exceedingly useful anesthetic in many conditions when ether and chloroform cannot be employed. If freely given, it causes complete muscular relaxation, but in the early stages of its inhalation it often produces muscular rigidity.

Nitrous Oxid Anesthetic Apparatus.—The use of nitrous oxid as a general anesthetic has been much simplified since the gas in liquefied form was made a commercial product and sold in steel bottles or cylinders, which can be safely transported any distance. The best of these cylinders are made of seamless steel, in three standard sizes, holding respectively 100, 250, and 450 gallons of nitrous oxid. They are equipped with a screw valve whose coned end works in a vulcanite seat in the neck of the cylinder. The valve is operated by a removable wheel-key, and protected by a screw-cap when not in use (Fig. 490).

One of the most convenient apparatus for the exhibition of nitrous

oxid with these cylinders is the Universal Gas Stand, made by the S. S. White Dental Mfg. Co. (Fig. 491). It is simply a substantial cast-iron base, mounted on castors, with coned socket for the cylinder and carrying an upright to support the yoke connection, gas-bag, and inhaler. It occupies a floor space of 12 x 13 inches, and is made for one or two cylinders, of which it will take any of the standard sizes. The yoke connection holds the cylinder firmly in its seat and secures a metal tube to the opening of the cylinder valve, through which the gas flows to the gas-bag by means of rubber hose. The gas-bag helps to regulate the pressure and to prevent waste of gas. It is gas-tight, and holds enough gas for the usual administration.

The inhaler is connected to the gas-bag by silk-covered rubber hose of ample capacity. The inlet for the gas is an opening in the main body of the inhaler over the stem, to which the hose is attached. A sliding internal tube, which projects at the rear, has a similar opening which is normally held away from that in the main body by a coiled spring. Pressure on the cap of the tube brings the two openings into juxtaposition and the gas flows. The sliding tube is perforated around its circumference, where it projects, just inside of the cap. These perforations admit air, which the patient breathes at the beginning of the administration, the gas being then admitted by pressing the cap. Removing the pressure shuts off the gas.

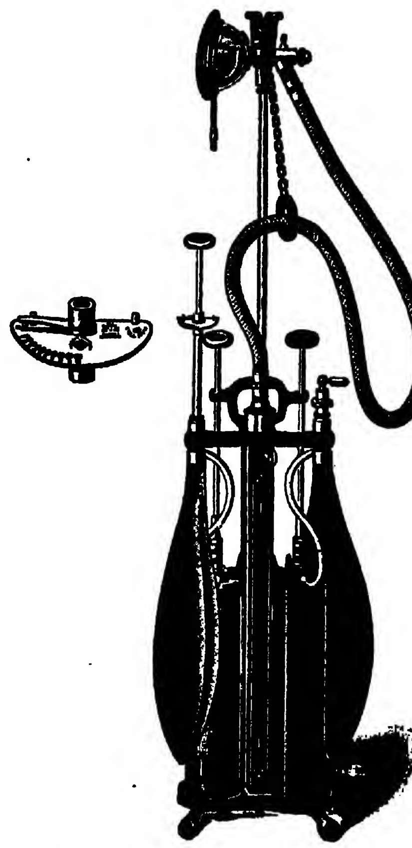

FIG. 490.—NITROUS OXID AND OXYGEN APPARATUS, NON-ASPHYXIAL METHOD.

For two cylinders, one each of nitrous oxid and oxygen.

The face-piece of the inhaler is made of transparent celluloid, permitting a clear view of the patient's lips, with an inflatable rubber hood to secure close adaptation to the face. The inhaling and exhaling valves are thin mica discs lying loose in open metal cages, so arranged that in respiring the former is opened and the latter closed, the reverse action occurring in expiration. It is impossible, with this inhaler, for the patient to rebreathe the expired gas, which is automatically

gotten rid of. The entire operation of the inhaling apparatus, in fact, is automatic, except the opening of the inlet.

During the past few years the non-asphyxial method of inducing nitrous oxid anesthesia, as proposed by Dr. Frederick Hewitt, has been gaining ground. This method consists in supplying a proportion of pure oxygen, usually less than 10 per cent., with the nitrous oxid. The effect is the elimination of the asphyxial symptoms of the anesthesia, the patient having much the appearance of one sleeping normally. This method requires a little longer time to produce the full anesthetic effect, but the impress is also somewhat more lasting. Another advantage is that the anesthetic state is readily prolonged almost indefinitely.

A very effective apparatus for this method, in its main features much like that just described, but with the necessary modifications, is now on the market. The base carries two cylinders, one of nitrous oxid, the other of oxygen, and a substantial standard, to the top of

FIG. 491.—INHALER NO. 4 WITH CELLULOID FACE-PIECE.

which is attached a hollow double yoke supporting the gas-bags at its ends, and a mixing chamber at its center. (The bag and the cylinder for oxygen are red, those for nitrous oxid, black.) Rising from the standard is a metal support for the inhaler and tubing. The apparatus has also the necessary keys and valves for controlling the supply of the gases. That for the admission of oxygen to the mixing chamber is equipped with a gag-plate to govern the percentage of oxygen supplied. With this apparatus either gas can be administered separately or both together.

When the gas is to be given, the patient should lie on one side or in the dorsal position, and care should be taken that the head is in the same axis as the vertebral column and not greatly flexed or greatly extended. It is often advisable to place between the teeth a small wooden plug to keep the jaws apart, and this is essential if there is reason to believe that the nasal passages are obstructed or if the opera-

tion is upon the mouth. To this wooden plug should be attached a string, so that when the jaw relaxes and the plug is set free, it cannot be drawn into the respiratory passages, or if this accident does occur, it can be readily withdrawn by traction on the string. After the mask is applied the anesthetizer should observe whether the valves move freely with inspiration and expiration. This observation is important not only because it shows that the apparatus is in working order, but also because it indicates that the face-piece fits well enough to prevent inspiration and expiration, taking place at the sides.

Usually it is best at the beginning to give no oxygen, or a very small percentage of it, since if more than 10 per cent. is used, a condition of excitation is prone to develop. The supply of both gases is regulated by means of the keys, and the skilful administrator constantly adjusts these keys to the needs of the patient, governing his movements by the resistance of the patient to the anesthetic and by a general consideration of the type of the case which is to be anesthetized. If any tendency to excitement develops, the oxygen should be cut off and the nitrous oxid pushed. In surgical operations which are prolonged over some minutes fresh oxygen should be allowed to escape into the bag every few seconds, and the need for the oxygen increases with the length of time that the nitrous oxid is given. As a rule, the anesthesia develops in about one or two minutes after the face-piece has been applied and the gas turned on.

Although nitrous oxid is the safest of all the anesthetics, it in one sense requires more skill in its administration than any of the others, because it is essential, on the one hand, that excitement be avoided, and, on the other, that too deep an anesthesia be not produced. In feeble patients and in children it often is wise to give oxygen from the beginning to the end of the administration of the nitrous oxid, whereas in powerful men it is often advisable that no oxygen be given, at least for the first few minutes of the anesthesia. Occasionally, if the operation is a long one, some fresh air is also allowed to enter by the side of the mask. If the breathing becomes obstructed and stertorous, the jaw should be pressed forward, as it is when this symptom develops under ether, that oxygen should be freely given. Hewitt states, however, that he has administered nitrous oxid for a period of thirty-five minutes without allowing even one breath of air.

As soon as surgical anesthesia is produced by nitrous oxid, the respirations which, in the early stage, have usually been deep and hurried, become remarkably quiet and entirely regular, and this is particularly so if some oxygen is allowed the patient. An advantage in administering oxygen with nitrous oxid is that its use diminishes, or puts aside, cyanosis and turgescence of the face and neck, which is an important factor when the patient has large adenoids and tonsils, or suffers from hypertrophy or hyperemia of the mucous membrane covering the turbinated bodies.

The following signs are indicative of the fact that surgical anesthesia has been produced by nitrous oxid; quiet breathing with loss of con-

junctival reflex, fixation, or slight oscillation of the eyeball and flaccidity of the arms. Rarely, however, fixation of the muscular system is present instead of relaxation, particularly if the patient be an alcoholic.

While there can be no doubt that the time required for the production of anesthesia when pure nitrous oxid is used is less than it is when some oxygen is given, the delay caused by oxygen is so slight that it need not be considered in most cases, the delay rarely being greater than two or three minutes.

Nitrous oxid is to be avoided if there is marked atheroma, particularly if there is also high arterial tension already present, because it causes a very sharp and marked rise of arterial pressure, and so may cause a cerebral apoplexy. So, too, the presence of a high arterial tension with a feeble first sound of the heart indicating that this organ is weakened or tired should make us careful in its use, lest the increased labor thrown on the heart by the rise in blood-pressure cause a cardiac breakdown. (See Preparation of the Patient for Surgical Anesthesia.) Cardiac dilatation, with or without a valvular lesion, is a contraindication to its use, as is also aortic regurgitation. When general muscular relaxation is essential, nitrous oxid cannot be relied upon. Conversely, there are a number of states in which nitrous oxid gas is distinctly the anesthetic to be employed in preference to ether or chloroform. In all brief operations it is generally the best anesthetic because it speedily produces anesthesia, and usually permits the patient to go his way with no after-effects. For the induction of general anesthesia prior to the use of ether and chloroform it is very advantageous in many instances (see Combined Anesthesia).

THE ADMINISTRATION OF ETHYL CHLORID.

The administration of ethyl chlorid cannot be satisfactorily performed by means of an open inhaler, such as that of Esmarch, since, even if large quantities of the drug are used, anesthesia develops too slowly, and not infrequently a condition of excitement is caused which renders the patient difficult to control. In other words, ethyl chlorid is one of the anesthetics which is best given by means of a closed inhaler. Probably the best form is Luke's ethyl chlorid inhaler (Fig. 492) or Hewitt's modification of Clover's inhaler. This consists of a face-piece and bag, the latter being fitted, at the extremity furthest from the inhaler, with a small stop-cock, which, in turn, is introduced into a glass tube, which is provided with a vulcanite collar. The glass tube, which has a capacity of about 10 cc., is then charged with from 2 to 5 cc. of ethyl chlorid, and attached to the bag, the stop-cock being closed. A pair of jaw forceps are introduced between the teeth, so as to keep the jaws slightly apart. The face-piece is then applied closely to the face in such a way that the patient inflates the rubber bag with his expired air. At this moment the stop-cock is turned, and the glass tube is tilted so that its contents enter the bag. Where such an apparatus is not at hand, Clover's ether inhaler may be em-

ployed. (See Article on Ether.) In other instances a metal or glass funnel may be inverted over the patient's face, the hands of the anesthetizer being placed on each side to make it as nearly air-tight as possible at the edges. Before the funnel is used, a small piece of gauze or absorbent cotton is placed in it, and upon this, through the small end of the funnel, is sprayed the ethyl chlorid from the tubes in which the drug is sold.

The quantity of ethyl chlorid which is necessary to produce anesthesia depends, to a great extent, upon the characteristics of the patient, upon the amount of air which the patient inhales simultaneously, and upon the method by which the drug is given. If the inhaler with a bag is used, usually from 1 to 2 cc. are sufficient to produce anesthesia in children, and 3 to 4 cc. will anesthetize most adults, but 4 to 5 cc. may be required for very strong men and alcoholics. In the latter class, however, the drug is not safe. When given by this closed method, anesthesia is produced in a few seconds, and usually without any discomfort, but if the vapor is pushed too freely in the first few inhalations, some holding of the breath may come on, and muscular rigidity is not infrequently met with, even if the drug is not given too freely. In powerful men a stage of excitement may develop even if the closed inhaler is used. Generally, the respirations immediately become full and more rapid, but remain regular. The face becomes flushed, the eyes fixed, the conjunctiva becomes insensitive, and the pupils dilate. If the respirations become markedly stertorous, the administration of the drug should be stopped or a little air allowed. McCardie states that occasionally muscular rigidity may become so marked that the jaws become fixed, and opisthotonos may develop. The pulse is usually slow and the blood-pressure falls. As with amyl nitrite, so with ethyl chlorid, the effects of the drug are often more marked after it is removed than while it is actually being inhaled; an important point to be remembered in its administration. This phenomenon is probably dependent upon the fact that the drug continues to be absorbed from the pulmonary alveoli, even though the inhaler may have been removed from the nose and mouth.

FIG. 492.—LUKE'S ETHYL CHLORID INHALER.

Although there can be no doubt that ethyl chlorid is a very satisfactory anesthetic because of its agreeable character and of the rapidity with which it produces anesthesia, there can be also no doubt that it is as dangerous as chloroform, if not more so. Statistics would seem to

prove that its mortality rate is from 1 in 2000 to 1 in 3000. In 5575 cases reported by Lee, to which ethyl chlorid was given in the Pennsylvania Hospital, there were 5 deaths—a mortality of about 1 in 1000.

The use of ethyl chlorid prior to the administration of chloroform is thought by those who have used it most to be inadvisable, since the rapid transition from a drug which markedly stimulates respiration and probably lowers blood-pressure, to another which markedly depresses the respiration and the circulation as well, may be dangerous. These views are in accord with those of McCardie and of Knight.

The accidents which have occurred from ethyl chlorid have, many of them, developed with startling suddenness.

The chief indication for the use of ethyl chlorid would seem to be for minor operations in children, to whom it is best given by placing a piece of lint in the palm of the hand, which is then held in a cup-like form over the mouth and nose; the ethyl chlorid is then sprayed on this lint, with the result that anesthesia is rapidly produced, and there is little danger of too much of the drug being administered. It seems to be universally recognized that ethyl chlorid is unsuitable for prolonged operations.

ETHYL BROMID.

Ethyl bromid, when poured upon the hand, should evaporate rapidly, leaving no residue or odor, and produce a marked sensation of cold. It should not give a precipitate with silver nitrate, and when mixed with concentrated sulphuric acid, no discoloration should ensue.

Although ethyl bromid has been before the profession as a general anesthetic since 1849, when Nunnelen, of Leeds, strongly recommended it, it has not been widely employed, and the researches which have been made concerning its physiologic effects are very few. Indeed, the only research with which I am familiar concerning its physiologic action upon animals is that which was made at my suggestion by Thornton and Meixell (Therap. Gaz., September 15, 1892) in the Laboratory of Experimental Therapeutics at the Jefferson Medical College. According to their investigations, the dominant action of the drug is upon the respiratory and not upon the circulatory system. Its influence upon both of these functions is distinctly depressant, although this effect is not marked unless it is given in very large doses. It causes a fall of blood-pressure and simultaneously slows the pulse, probably through a stimulation of the inhibitory nerves of the heart. In America its most enthusiastic supporters have been Levis and E. E. Montgomery. It has not been given in a sufficient number of cases to permit of a large array of statistics being collected, but the consensus of opinion is that it is more dangerous than chloroform. Its advantages are the speed with which it produces anesthesia, and the rapidity with which its effects pass away when the drug is withdrawn with the inhaler. Not infrequently at or about the moment of onset of surgical anesthesia under its use a curious condition of muscular fixation is developed, somewhat resembling that seen at the moment of dissolution, which,

to a novice employing it, is exceedingly alarming. This rigidity gives place in a few seconds to muscular relaxation.

To produce satisfactory results the drug must be given in very concentrated form in a practically air-tight inhaler, which is placed closely against the patient's face, as much of the atmosphere being excluded for the first few respirations as possible. Some of the accidents which have been credited to it are probably due to the substitution of ethylene bromid for ethyl bromid, and possibly to the employment of ethyl bromid, which may have undergone chemic change by reason of exposure to light and air. Bromid of ethyl should always be kept in hermetically sealed dark-colored bottles in a dark place, and samples which have been freely exposed to the air during the administration of part of them to a patient had better be discarded. The drug is unsuitable for prolonged surgical operations. It has given its best results in labor, where the rapidity of its effects and the fleeting character of its anesthesia at once promptly relieves the patient, and then as promptly permits the patient to come back to consciousness. Another advantage of ethyl bromid is that it seldom produces disagreeable after-effects, and, therefore, a patient who takes it in an office can usually go out into the street within a short time without difficulty. Because of its failure to produce muscular relaxation, except when the anesthesia is profound, it does not lend itself to many surgical conditions in which relaxation is a necessary factor. Nausea and vomiting rarely follow its use. It sometimes produces a garlic-like odor on the breath, which may persist for several days. The quantity of ethyl bromid necessary to produce anesthesia varies from 45 minims to 3 drams if a tightly closed inhaler is employed, and most of this should be poured upon the inhaler at once, instead of being added drop by drop. The best inhaler for its use is the so-called Hawley inhaler, Rendel's mask, or an Ormsby inhaler. Silk, in 130 cases, found that it produced anesthesia on the average in sixty-six seconds, and that the anesthesia lasted forty-six seconds, and that when the inhalation exceeded two minutes, the after-effects were likely to be troublesome. Chisholm, who reported 300 cases to which ethyl bromid was given, also found that the time required to produce surgical anesthesia was not more than sixty seconds. Cases are on record in which long operations lasting more than an hour have been carried on under ethyl bromid, but these are curiosities in literature, and the practice is to be condemned. The accidents which have been reported under its use have consisted in sudden cardiac failure developing early in its use, and respiratory paralysis developing late in its use, and occasionally cyanosis and cardiac engorgement. Among the after-effects which are sometimes annoying are hysteric manifestations.

THE ADMINISTRATION OF ANESTHETICS IN SEQUENCE.

The fact that ether and chloroform induce unconsciousness with comparative slowness has led to the primary use of nitrous oxid gas or ethyl chlorid in order that the stage of primary anesthesia might be

made exceedingly brief. This is particularly advantageous when ether is employed, since, under these circumstances, the patient does not suffer from any of the disagreeable sensations which are produced by this drug when first inhaled, time is saved, and struggling is avoided. There can be no doubt whatever that the primary use of nitrous oxid for this purpose is very wise in a large proportion of cases. Its safety, the speed with which it produces its effects, and the slight influence which the gas exercises upon vital functions permit the ether to be given with confidence after anesthesia is developed.

The employment of ethyl chlorid for this purpose is not to be looked upon with favor. Unlike nitrous oxid, it acts powerfully upon respiration and circulation, and statistics up to the present time show that it is more dangerous than chloroform. In addition to these facts it is disadvantageous to expose the patient alternately to the effects of drugs which act differently but powerfully upon vital centers. In cases in which the early effects of ether are dreaded, and the anesthetist is tempted to employ ethyl chlorid, it should be remembered that the chances of the patient are better with ether alone skilfully given than they are with ethyl-chlorid-ether sequence.

Nitrous oxid-ether-chloroform sequence has equally great disadvantages, since it exposes the patient alternately to the high arterial pressure of nitrous oxid, to the cardiac stimulation and respiratory depression of ether, and to the universal depressant effect of chloroform.

ANESTHETIC MIXTURES.

A large number of mixtures composed of various anesthetics have been recommended from time to time. They are much more popular in England than they are in this country or in Europe. The most common of them is the so-called A. C. E. mixture, composed of alcohol, 1 part; chloroform, 2 parts; ether, 3 parts. It was supposed at one time that the alcohol increased the stupefying effects of the ether and chloroform, and also served to act as a stimulant upon the heart, and so antagonized any depression produced by the anesthetics. A better knowledge of the influence of alcohol has proved this idea to be fallacious. In order to obtain a mixture in which the three ingredients will volatilize with about equal rapidity, the alcohol should have a specific gravity of 0.795; the chloroform, 1.497; and the ether, 0.720. The advantages claimed for this mixture are that the ether acts as a stimulant, while the chloroform acts as a depressant. The number of accidents under the use of this mixture is very considerable, and it is by no means as safe as ether, although it is less dangerous than chloroform. Billroth's mixture is another A. C. E. mixture, which consists of one part of alcohol, three of chloroform, and one of ether, and is largely used in Germany. It is more dangerous than the English A. C. E. mixture. A more popular mixture is the so-called C. E. mixture, often called also the Vienna mixture, which consists of 1 part of chloroform to 3 of ether. It is commonly given by means of Hewitt's C. E. inhaler.

SCOPOLAMIN-MORPHIN ANESTHESIA.

The scopolamin-morphin method of producing surgical anesthesia has been widely employed within recent years. Much conflicting testimony has been presented concerning it. It is noteworthy that recent reports have been less enthusiastic than the earlier ones, and, as its use became more widespread, the number of instances in which untoward effects developed have increased. The conclusions which were arrived at by Whiteacre seem to me to cover the facts as they exist to-day, and are as follows:

1. Scopolamin-morphin narcosis is not devoid of danger.
2. The use of scopolamin and morphin alone for surgical narcosis is not justifiable, and in the experience of the author is not practicable.
3. A single dose two hours before operation lessens the discomforts attendant upon the operative procedure to a high degree, and may obtain a definite place in surgical practice.
4. Four deaths have occurred in a series of 2400 cases, which have been so definitely related to the use of this method of narcosis that they may be called scopolamin deaths, although there was an absence of an autopsy demonstration.
5. These deaths have been reported as occurring with a picture of alkaloid poisoning, and heart failure has been given as a direct cause of death (Landau).
6. A fatty degeneration of the liver and kidney has been produced in animals by the use of repeated doses of scopolamin alone, and of scopolamin in combination with morphin.
7. This method of producing or assisting narcosis cannot yet be recommended for use in general practice, in spite of the great advantage it seems to offer (Kochmann).

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CHAPTER LXXXI.

LOCAL AND SUBARACHNOID (SPINAL) ANESTHESIA.

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LOCAL ANESTHESIA.

The preceding chapter has treated the subject of general anesthesia (narcosis). In this chapter it will be shown that freedom from pain, without disturbance of consciousness, may be produced either by the action of an anesthetic upon the terminal branches of the sensory nerves in an organ (*terminal anesthesia*) or by the action of a similar agent upon any point of a sensory nerve in its course from the organ, but still outside of the spinal canal (*regional anesthesia*) or within the spinal canal, in the subarachnoid space (*subarachnoid anesthesia*). Thus, for example, a greater or smaller part of a foot may be rendered insensible by locally injecting into the skin and other tissues of the foot a weak cocain solution. This is terminal anesthesia, by benumbing the terminal nerve branches *in loco*. The same area of the foot or the entire foot may be made insensible by an injection of a stronger cocain solution in the leg immediately *around* or *into* the larger branches or trunks of the posterior tibial, the peroneal, and the long saphenous nerves. By such a *perineural* or *endoneural* injection the sensory nerve-conduction to the brain is cut off at the point at which the injection is made. The nerve is at that point, for the time being, physiologically amputated or "blocked" (Corning, Crile, Matas, and others). An anesthesia thus produced is termed *regional*. But the foot may also be made insensible by the injection of a cocain solution into the subarachnoid space around the nerves in the cauda equina. The roots of the sciatic nerve, together with all the other nerves in the cauda equina, are thus paralyzed. The cutting off of the sensory conduction occurs in the nerve (the roots of the sciatic nerve) within the subarachnoid space. As a rule, this produces a sensory paralysis of at least the sacral and the greatest part of the lumbar plexuses. This anesthesia can, therefore, not be called regional, but, like the regional, it is a *conduction anesthesia*. *In*

[1] The death of Professor Lennander was a great loss to surgery and to his many friends. For years he had suffered from valvular heart disease, and could spend only six hours of the day out of bed; yet by his energy and assiduity he achieved an international reputation and contributed greatly to the progress of surgery.

An attack of apoplexy and his death occurred soon after he had finished the section on Local Anesthesia and was about to write the remaining section on Spinal Anesthesia. His assistant, Dr. Fredrik Zachrisson, who was familiar with his views kindly consented to complete his chapter. (W. W. K.)

conduction anesthesia the nerve conduction only is broken, while in general anesthesia (narcosis) the central organs in the brain, and in terminal anesthesia the nerve-endings and probably also the peripheral end-organs, are paralyzed. Terminal anesthesia is, therefore, certainly a paralysis of the nerve-conduction in the smallest peripheral nerves, but in addition it is probably a paralysis of the end-organs of the sensory nerves. This, however, cannot be demonstrated. An injection of an anesthetic in the subarachnoid space acts upon the sheathless nerves in much the same way as does an injection into a peripheral nerve-trunk.

Local anesthesia has in this treatise a double meaning. The expression is used—(1) as in the title, in a *wide* sense, equivalent to terminal and conduction anesthesia, excluding the subarachnoid; (2) in a *narrow* sense, equivalent only to that form of anesthesia which is obtained by more or less filling (infiltrating) the tissues of a part of the body with an anesthetic. This local anesthesia in a narrow sense consists of a combination of a terminal anesthesia and what might be termed a local conduction anesthesia. By the infiltration of the operative field both the large and small sensory nerves contained therein, as well as their terminal branches, are paralyzed. Local anesthesia in a narrow sense is an expression used to distinguish it from *regional conduction anesthesia*, which, as has already been said, occurs after the injection of an anesthetic *into* or at only one place *around* a large nerve or nerve-branch.

LOCAL ANESTHESIA—TERMINAL AND CONDUCTION ANESTHESIA, EXCLUDING SUBARACHNOID ANESTHESIA

An organ endowed with sensation may have all the four commonly described modalities thereof, viz., sense of *pain*, *pressure*, *heat*, and *cold;* another organ has apparently the sense of *pain* only.

In order successfully to practice *local anesthesia* it becomes necessary to know the main distribution, especially of the pain-conducting nerves, throughout the body.

Ever since the year 1900 I have endeavored to make observations on sensation in man, both at operations, with local anesthesia, and on other occasions when neither anesthesia in any form nor anodynes of any kind had been used, as in cases of preternatural anus, articulations laid open by trauma, partly exposed kidney, etc. For the internal organs, the results at which I have arrived can be expressed in one sentence, which, after I had had the opportunity to examine intestines, stomach, gall-bladder, lungs, and other organs, some of them both in disease and in health, in 1901 I set up before me as a working hypothesis, viz., all internal organs receiving their nerve-supply only from the sympathetic nerve and from the vagus, below the branching off of the recurrent nerve, have no sensation. According to my observations, therefore, the abdominal and pelvic viscera[1] are devoid of nerves to convey the sense of pain, pressure, heat, or cold.

These organs have no sensation either in health or in disease. The serous membrane surrounding the abdominal cavity—the parietal

[1] About the urinary bladder, see p. 1047.

peritoneum—is, however, on the contrary, very sensitive to pain. The placing, for example, of sterile saline compresses during an abdominal operation, between the viscera and the parietal peritoneum, causes much pain, as does also traction upon the attachments of the mesenteries to the abdominal wall. But placing the compresses between the viscera, at the same time avoiding the parietal peritoneum, occasions no pain.

The parietal peritoneum derives its pain-conducting nerves from the seven lower intercostal, the lumbar, and the sacral nerves, and the entire diaphragm, except the rim, from the phrenic nerves. The rim is supplied by the seven lower intercostal nerves. M. Ramström, professor of anatomy in Upsala, was the first clearly to trace the innervation of the parietal serosa and subserosa. Through my researches I consider it to be an established fact that the parietal peritoneum of the anterior abdominal wall is not endowed with nerves or end-organs for the perception of pressure (touch), heat, or cold, although this serous membrane is very sensitive to pain. So far it has not been possible to make such observations on other than the *anterior* parietal peritoneum. The necessity of exerting the slightest amount of traction on the root of a mesentery causes great pain, but otherwise, according to my own observations, the mesenteries are without sensation. Braun does not entirely agree with me on this point. He suggests that cerebrospinal nerves from the posterior abdominal wall may occasionally stray into the mesentery of the intestines.

The parietal peritoneum adjacent to the foramen of Winslow and the peritoneum at the lower opening of the thorax, along the costal cartilages, appear to me to be areas which are especially sensitive to pain. In regard to the urinary bladder my observations are very scant. I have found that the bladder serosa examined through an abdominal section is insensible. In suprapubic cystotomy, when only the abdominal wall but not the bladder has been anesthetized, one may cut into, grasp with artery-clamps, and stitch the bladder-wall often without causing any pain. Great care must, however, be taken not to pull upon the attachments of the bladder, particularly when the patient has cystitis, which naturally is accompanied by a lymphangitis with increased sensibility of the surrounding connective tissue. The urethra, even the membranous portion, is certainly very sensitive. Regarding the prostatic portion I am not prepared to express an opinion. Bottini's operation, which we have always performed without general narcosis, has not seemed to be very painful.

When the fatty capsule of the kidney has been separated from the fibrous capsule, neither the fibrous capsule nor the kidney parenchyma shows any sensation. So soon as the kidney has been brought up into the incision, the inhalation narcosis may, therefore, be instantly diminished, provided it be not necessary to stretch upon the hilus. The ureter and the pelvis of the kidney, I believe, are not themselves endowed with sensory nerves, but they are situated closely behind, and are partly very intimately connected with, the sensitive posterior parietal perito-

neum, and they are also surrounded by tissues richly supplied with nerves. Every energetic contraction, every sudden and marked dilatation of the pelvis or the ureter is, therefore, necessarily accompanied by sensations of pain. The same is true of the ductus choledochus.

The sensory conditions of the testicle are very difficult to determine. The connective tissue in the hilus and along that part of the epididymis not covered by serous membrane has pain-conducting nerves, probably derived partly from the external spermatic (lumbar plexus) and the pudendal (sacral plexus) nerves. Those parts of the testicle and epididymis which possess a serous covering have, according to my observations, no sensation. The parietal portion of the tunica vaginalis propria behaves, in regard to sensation, as the parietal peritoneum within the abdomen. The spermatic cord has sensation through the external spermatic nerve. The vas deferens and the vasa spermatica are, according to my observations, accompanied only by sympathetic nerves from the abdominal cavity.

The parietal pleura and the parietal pericardium are very sensitive to pain (the intercostal and both phrenic nerves). In resections and extirpation of costal cartilages in front of the heart I have found that the connective tissue behind the thoracic wall and the pericardium is particularly sensitive to pain. The lung has no sensation, and the same is, in all probability, true of the heart. Harvey noted that the heart is insensible. Traction upon the hilus of these organs is likely to be extremely painful, as is also a sudden pull upon the parietal pericardium.

After the thyroid gland has been laid bare, an operation upon it is painless, provided there is no pulling upon the adjacent connective tissue. After having completely bared the trachea for a tracheotomy, I was able to cut through its anterior wall and hook up the mucous membrane without causing pain.

As is well known, the brain has no sensation. The same is true of the pia arachnoid. It is also true of the dura mater on the convexity of the brain down toward the zygomatic arch, where surgical interference, but especially pulling on the dura mater, is painful. Beneath the occipital bone the dura mater has the sense of pain (Braun), but not beneath the frontal bone (G. Nyström). In laying bare the dura mater beneath the mastoid portion of the temporal bone I have found that this portion of the dura, as well as the transverse sinus, has no sensation.

When scraped free of periosteum the cranial bones have no sensation, with the exception, naturally, of all bones traversed by sensory nerves; above all, the inferior and both superior maxillæ. When the periosteum has been completely scraped away from the mastoid portion, the antrum and other air-cells may be painlessly opened, because neither the bone nor, so far as I have yet been able to ascertain, the mucous membrane in these spaces has any sensation. It should be noted, however, that the mucous membrane in my cases has been badly damaged or destroyed by suppuration. The mucous membrane of the middle ear is extremely sensitive. That of the antrum of Highmore

and the lacrimal canals has sensation. I found the same to be true of the mucous membrane of the frontal sinus.

The entire integument, although in a varying degree, is endowed with all the four modalities of sensation, viz., the sense of pain, pressure, cold, and heat. The superficial connective tissue, the aponeuroses, and the muscles possess the sense of pain in a much less degree than the integument. Through these tissues the sensory nerves pass from the integument toward the great nerve-trunks and the spinal cord. In order, therefore, to operate painlessly on these tissues, it will be necessary either completely to anesthetize the entire operative field by one or more perineural or endoneural injections, or at a sufficiently long time before the operation to saturate the entire operative field with a weaker anesthetic solution, thus absolutely cutting off all transmission of pain from these tissues, both through their own terminal nerves and also through nerves which may traverse them. In cutting these last nerves before they have had time to become paralyzed the patient will often say that it feels like an electric shock. The tendons are believed to have little or no sensation. I found, however, that the ligamentum patellæ, at the tubercle of the tibia, was very sensitive both to the knife and to the scissors. The connective tissue around the tendons has sensation, *e. g.*, a highly developed sense of pain exists in the periosteum, the perichondrium, and in the articular synovial membranes. But the bone-substance, the bone-marrow, and the cartilages do not possess any of the four modalities of sensation. Provided a part of a bone has been scraped clean of periosteum, any operation may be done painlessly upon it. If the medullary canal of a long bone has been opened at any point, the marrow may be painlessly scraped out for the entire length of the bone. If the anterior wall of a sequestrum cavity has been opened under local anesthesia, it will then be possible painlessly to scrape and clean out the bone posteriorly, even down to the healthy periosteum, provided only care be taken not to touch the periosteum. Articular surfaces covered with cartilage have no sensation, nor the interarticular fibrocartilages of the knee-joint. Arteries and veins, when separated from the adjacent connective tissue, have no sensation. Tumefactions do not have sensation. Granulations have no sensation. In case they spring from a surface which is not sensitive, *e. g.*, from a bone deprived of its periosteum, they may be painlessly scraped, burnt, etc., or if they are situated at the edge of a skin-ulcer, they may be carefully cut with scissors or with a razor without producing any pain, but to scrape them off or to burn them would cause as much pain as would operating on normal skin.

History of Local Anesthesia and Anesthetics.—Nerve Pressure; Anemia.—That local pressure upon a nerve will produce motor and sensory paralysis is a matter of daily experience. In surgery the attempt was made long ago to utilize this experience by applying the so-called *ligation anesthesia, i. e.*, a rubber tube or a bandage, around a finger or an extremity. It has been believed by many that arresting the circulation would be sufficient to produce insensibility. This is

an error. According to Braun's experiments upon himself, arrest of the circulation at the base of a finger produces, aside from paresthesia and a feeling of numbness, at most a paralysis of the sense of pressure; even after two hours pricking the finger-tip with a needle was rather more than ordinarily painful.

On one occasion Braun obtained almost complete insensibility of his own middle finger after ligating the basal phalanx, but the finger remained insensible even for several months after the rubber-tubing had been removed. Plainly, a pressure trauma of the nerves remained. With Braun, I believe that the old-time surgeons were right in believing that insensibility could be obtained only by a pressure which is severe enough to injure the nerve. It is well known that the motor nerves are more easily injured than the sensory nerves, and that the motor conduction is restored more slowly and often less completely than the sensory. Ligation anesthesia, therefore, is inadvisable.

Cold.—A mixture of ice and common salt in a gauze bag was used by Arnott (1848) to render the skin insensible to incisions. Richet (1854) and others used sulphuric ether, allowing it to evaporate upon the skin. Through Richardson's invention of the ether or rhigolene spray (1866) a practically useful method was obtained. Under the play of an ether spray the mercury in a thermometer will rapidly drop to $-15°$ to $-20°$ C. With the evaporation of the ether upon the skin this first becomes red, and after a few minutes it gets white and hard and completely insensible. It is frozen. If the warm blood-stream is prevented from flowing through the tissues, *e. g.*, if the ether spray be applied peripherally to an Esmarch's bandage, the freezing will be quicker, will penetrate deeper and last considerably longer, but there is always some danger of gangrene. As soon as a tissue is frozen, the terminal branches of the sensory nerves become paralyzed (*terminal anesthesia*). After thawing, sensation immediately returns, and the tissue remains for some time hyperesthetic, but the tissue will not suffer injury if the freezing has been of short duration. The process of freezing is attended with pain, and so also is the thawing, and this pain may last a long time. At the present time the ether spray is not often used.

Ethyl chlorid, or a mixture of ethyl chlorid and *methyl chlorid,* commonly called *anestil,* is being used instead. The liquid is contained in glass or metal tubes. The heat of the hand is sufficient to cause it to escape in a forcible jet through a fine opening as soon as the metal screw-cap has been removed. With any of these liquids the freezing is done much more quickly than with ether spray. The incision should be made immediately after the skin has become frozen. Personally, I have never seen any harm to the skin from ethyl chlorid or from anestil, but, on the other hand, I have never attempted to produce deep, *i. e.*, subcutaneous anesthesia.

That ether vapors are very inflammable and explosive is well known; ethyl chlorid and methyl chlorid do not, however, ignite from an open flame or a thermocautery.

Braun has tried to produce regional anesthesia upon himself by

means of ethyl chlorid on the skin over the ulnar nerve, behind the internal condyle, and also on the skin over the radial nerve, above the wrist. As soon as the freezing reached the nerve, he experienced an intense, characteristic pain within the area of distribution of the nerve. Within the area of the radial nerve anesthesia occurred, but only partly along the ulnar nerve, because it was necessary to discontinue the freezing as the pain became too severe. Two minutes after the ethyl chlorid had been withdrawn the pain conduction was restored. The skin was badly ulcerated in both places.

Ethyl chlorid or *anestil spray* is useful to render the skin painless to a single incision. This may very well have the length of from 10 to 20 cm. If the skin be inflamed, the freezing may be very painful. Personally, I use ethyl chlorid or anestil in order to render the skin rapidly perfectly insensible in cases when, for local anesthesia, I have injected a novocain-adrenalin solution deep into the subcutaneous tissue, but have no time to wait for the paralyzing effect of this solution upon the nerve conduction from the skin. The freezing is then done quickly and painlessly. I likewise use ethyl chlorid in case I need to lengthen the skin incision when operating under local anesthesia or light narcosis. Ethyl chlorid is excellent to diminish the pain from secondary suturing.

Isotonic Solutions.—The nerves, as well as all other tissues within the body, in order to functionate normally, must be surrounded by and permeated with a nutritive fluid, the main constituents of which are water, albumin, and salts, which, when present in a certain constant ratio, determine the osmotic equivalent of the fluid. In order that an aqueous solution of a salt may be injected into a tissue without causing any injury to it or any reaction from it, it is requisite that the salt be indifferent, *i. e.*, in every respect harmless, and also that the solution be isotonic with the blood, and that it be injected at body temperature. Among indifferent salts may be mentioned chlorid, sulphate, phosphate, and carbonate of sodium and other sodium salts. Should the injected solution not be *isotonic* with the nutritive fluid of the tissue, that tissue will be more or less injured. A *hypotonic* solution gives off water to the tissue and takes up its salts. The ratio of salts within the tissue is consequently altered. The tissue, in our case the nerve, becomes swollen and loses its microscopic structure. A *hypertonic* solution takes water away from the tissue, consequently it increases the ratio of salt and causes the nerve to shrink.

All isotonic solutions have the *same freezing-point.* The freezing-point of the blood is given at —0.55° to —0.57° C. A solution with its freezing-point at about —0.56° C. is consequently isotonic with the blood. A solution of sodium chlorid to be physiologic for the tissues of man must contain 0.92 per cent. of sodium chlorid; one that is physiologic for the tissues of the frog, 0.6 per cent. If a few drops of a 0.92 per cent. solution of sodium chlorid at body temperature be injected into the skin, it turns white and hard and becomes raised, forming a wheal. Its appearance is not attended by pain, and in testing its sensation with a pin, this is found to be unaltered. The wheal soon

disappears without leaving a trace. The injection of this isotonic solution of sodium chlorid, heated to body temperature, has produced no irritation of the nerves of pain in the skin (has caused no pain) and it has not paralyzed the nerves (has produced no anesthesia), and has in no way injured the tissue. If the percentage of salt in the 0.92 per cent. solution of sodium chlorid be successively diminished, injections into the skin of a healthy, normal forearm begin to be painful and are followed by anesthesia from a solution of 0.55 per cent. or less. The pain and the anesthesia increase *pari passu* with the diminution in the salt ratio, and are greatest when only pure distilled water is used. The injection of pure water is very painful, but the pain soon subsides and is followed by a sensory paralysis which lasts for fifteen minutes. Solutions which are greatly diluted will cause a lasting injury to the tissue. The wheal does not disappear, and a painful infiltration will remain for a long time. After an injection of pure water there occurs, not infrequently, even a superficial necrosis. Hypertonic solutions absorb, as before stated, water from the tissue, the nutritive fluid of which consequently becomes more concentrated. This causes pain and anesthesia of the sensory nerves and injury to the tissue. Pain and anesthesia occur when the solution contains about 2.5 per cent. sodium chlorid. The symptoms increase with an increase in the salt ratio. It is scarcely possible to make the injections stronger than 10 per cent., because the pain is unbearable.

Chemical Local Anesthetics.—By local anesthetics are understood certain chemical compounds, weak solutions of which, when brought in contact with sensory nerves, paralyze them without lastingly injuring them. This effect is dependent upon the presence, in these agents, of certain atom groups which Ehrlich calls anesthesiphorous atom groups. It is possible that just these atom groups enter into certain chemical combinations with the nerve substance, and that the nerve thus remains paralyzed until the newly formed compounds are split up and the poison is washed away by the circulating blood.

Cocain is the original type for a local anesthetic. Einhorn discovered its composition. He has thus made possible its synthetic production, and also opened the field for a great number of experiments of scientific and practical importance, leading to the discovery of new local anesthetics obtained by exchanging the non-anesthesiphorous atom groups of the cocain for other groups, different for each of the various new agents. Thus eucain, orthoform, anesthesin, and others have been obtained.

The local anesthetics are effective in great dilutions. In order that the solutions should have the same freezing-point as the blood, —0.56° C. and thus be physically harmless to the tissue, it is requisite that sodium chlorid in greater or smaller amount be added. Those solutions of various local anesthetics which have been made isotonic with the blood are afterward tested by injections in the skin-producing wheals. In this way there is then to be determined: (1) The smallest percentage of an agent which may be required to render the wheal anesthetic; (2)

the duration of anesthesia. At the same time it should be noted whether the skin becomes hyperemic, if a painful infiltration remains, etc.—in other words, whether the agent used in isotonic solution be injurious or not to the tissue.

Cocain.—This salt occurs in a white, crystalline powder, readily soluble in water and in alcohol. It is an alkaloid which affects all living protoplasm. It first excites, then paralyzes. In greater concentration it paralyzes immediately. Its effect is very ephemeral, producing no lasting harm to the affected protoplasm. Its effect is most readily understood by assuming that the cocain poisons the protoplasm by entering with it into combinations which are easily broken up. The products of the decomposition, among which cocain cannot be recovered, are slightly or not at all poisonous, and are carried away by the circulation. Cocain has the greatest affinity for the central nervous system, and next for the sensory and motor nerves. A few drops of a 10 to 20 per cent. cocain solution applied to the floor of the fourth ventricle cause immediate respiratory paralysis, but the animals may be saved by artificial respiration. Should a little cocain enter the circulation and be carried to the brain in a certain very weak concentration, the strength of which is known in the case of, for example, the rabbit, but not for man, restlessness, convulsions, and general paralysis make their appearance and are followed by death from respiratory failure. As soon as signs of respiratory failure appear in a case of cocain-poisoning, artificial respiration should be resorted to. This affords hope of recovery.

It is evident that in local anesthesia one must be careful that cocain solutions are not injected directly into the blood, neither in veins nor in arteries, and that in applications to mucous membranes and in subcutaneous injections the solutions are sufficiently weak to preclude the possibility of the cocain ever reaching the cerebral cortex or the respiratory center through the general circulation in a dose which, for these, the most sensitive organs, might prove toxic.

A maximum dose of cocain can never be fixed. Although so highly poisonous, especially for the central nervous system, it is, however, rapidly decomposed by contact with living protoplasm. The occurrence of poisoning and death depends, therefore, upon the degree of concentration of the cocain in the blood at the time it reaches the central nervous system. The German and the Swedish pharmacopeias have the maximum dose 0.05 gram. Weigand, in his collection of cases of poisoning and death from cocain, has recorded no fewer than 40 cases where very dangerous symptoms often followed the administration of only 0.01 to 0.05 gram, but in solutions of from 5 to 30 per cent. concentration. Czerny had a death from the injection of 7 cc. of a 1 per cent. cocain solution in the urethra.

From this it will be clear that cocain-poisoning can be avoided only by a technic so planned that none but doses absolutely harmless for the central nervous system may enter the general circulation.

How this is accomplished will soon be explained. Cocain has a

greater affinity for the sensory than for the motor nerves. The effect of cocain in a certain proper concentration upon peripheral mixed nerves is to abolish, first, the sense of tickling, then the sense of temperature, thereafter the sense of pain, and lastly the sense of touch (pressure), and only thereafter the motor faculty, which may remain unaffected although all the modalities of sensation have been paralyzed. During the retrogression of poisoning, the faculty of motion is the first to return, then the sense of pressure, next the sense of pain, and lastly the sense of temperature. Modern local anesthesia has been made possible through the discovery of cocain. Its birth may be dated back to the year 1884, when Koller announced that many operations upon the eye could be performed without pain after the instillation into the conjunctival sac of a few drops of a 2 per cent. solution of cocain. Cocain was soon in use for the anesthetizing of all accessible mucous membranes. The great importance of cocain, for example, in laryngology and rhinology, lay in the fact that not only does it abolish pain and the reflexes, but also that, through its astringent effect upon the smooth muscular structure of the vessels, it at the same time causes a temporary disappearance of swellings of the mucosa and submucosa, an effect which is of incalculable advantage in diagnosis and surgical technic, but which is now, however, even more surely attained by the use of adrenalin.

Injected into the tissues cocain became a useful anesthetic in other branches of surgery and in dentistry. In the beginning concentrated solutions of 2 per cent., 4 per cent., 10 per cent., up to 20 per cent. were used. For example, 5 drops of a 4 per cent. solution were injected subcutaneously, producing an anesthesia which was found to extend to a surrounding area in all directions. By creating such centers or depots of cocain one after another in a line it became possible to anesthetize quite a large area. The neurologist, J. Leonard Corning, of New York, was one of the first to realize how dangerous an agent cocain was. According to him, it was self-evident that an agent possessing an affinity so strong for the peripheral nerves must needs act as a poison to the heart and the central nervous system in case it should enter the blood in a sufficiently concentrated solution.

Corning (1885) and Goldscheider (1886) demonstrated on man that cocain breaks the conduction through a nerve, a fact previously demonstrated by physiologists on animals. Halsted and Raymond, as early as 1885, injected cocain around the lingual nerve and around the inferior dental nerve, to make painless tooth-extraction in the lower jaw. This marks the beginning of the perineural method of injection. Hall applied this method at the same time to the infra-orbital nerve.

Corning used weak solutions of cocain, from 2 to $\frac{1}{5}$ per cent. A solution of $\frac{1}{3}$ per cent. he considered especially serviceable if the circulation could be shut off after the injection. He first made an intracutaneous injection, followed by a subcutaneous one, and finally an injection into the deeper tissues. The injections should be completed in from three to five minutes, and should be immediately followed by

the application of an Esmarch bandage proximally to the site of injection. He did not apply the bandage before making the injection, for the reason that he wanted to use the capillary circulation for the distribution of the cocain. On the head, in the face, and on the trunk he attempted to shut off the peripheral circulation in the skin and subcutaneous tissue by metal rings, etc., covered with rubber-tubing and held in place with tapes. After the shutting off of the circulation one could still promote the spread of the cocain into the surrounding area, to a certain extent, by massage. With the removal of the bandage the insensibility was diminished after a few minutes, and had soon altogether disappeared. During the incarceration of the cocain by an occluding bandage major operations lasting even two hours were performed upon the extremities. Matas has rightly emphasized that one ought to diminish the pressure of the bandage on the nerve-trunks by placing soft pads over the nerves and by applying the bandage in a spiral manner. It is often not difficult to obtain complete local anesthesia distally to a circular bandage, but after perhaps three-quarters of an hour or one hour the patients begin to complain bitterly of local pressure from the bandage and of pain in the areas of the peripheral distribution of the nerves.

Before making the injections Corning was in the habit of applying a stasis bandage around the extremities, the neck, etc., in order to fill the veins distally to the bandage, thus causing them to stand out prominently. He then made his injections according to this map in order to avoid injecting the cocain directly into the blood. The same end may be obtained by following the advice of Recus, to inject the cocain only during the pushing forward or during the withdrawing of the needle. In deep injections of cocain in the vicinity of known vessel-trunks one should first introduce the needle attached to an empty syringe, and make suction. If no blood appear, cocain may then be injected.

Roberts (also in 1885) injected weak solutions in the skin and in the subcutaneous tissues. In the United States Halsted had also very early made a warm plea for the use of local anesthesia with cocain. At the instigation of Wölffler (1887) a number of observations on cocain and on major operations performed under cocain anesthesia were published. Soon, however, so many cases of poisoning and death from cocain were reported in all countries that many surgeons regarded cocain anesthesia as more dangerous than general narcosis.

Schleich at that time (1891, 1893, etc.) rendered great service to the cause of local anesthesia by demonstrating that solutions of cocain of $\frac{1}{10}$ per cent. and still weaker could be successfully employed if the tissues are infiltrated with the solution *under pressure.*

Conduction Anesthesia with Cocain.—A procedure which in many instances is of practical importance consists of excluding all nerve-conduction from the field of operation by making an injection all around it. Hackenbauch (1897) has described this procedure as an original method. Figuratively speaking, the operative field may be said to be

encased in a "shell" of tissue infiltrated with cocain, resulting in the paralysis of every sensory nerve passing through it.

In speaking of *conduction anesthesia*, a "perineural" or "endoneural" injection is, however, uppermost in one's mind. These terms, according to Braun, were first employed by Matas. The Germans usually attribute the *perineural* method to Oberst, who has been employing it since 1888 for anesthetizing fingers and toes. Important works on the perineural method have since appeared from the hands of Kummer, Krogius, Braun, and Hackenbruch. For perineural injections solutions of cocain of from ½ to 2 per cent. have been employed.

In *endoneural* injections the nerve is laid bare under local anesthesia with infiltration. Then a cocain solution, preferably of 1 per cent., is injected into the very trunk of the nerve, a globular swelling appearing at the site of injection. The nerve-conduction is broken almost instantly, and the anesthesia lasts from twenty-five to thirty minutes (Crile).

Already in 1887 Crile amputated a leg after a preceding injection of cocain into the crural and sciatic nerves. He has later practised injections in the brachial plexus above the clavicle, with simultaneous temporary forcipressure of the subclavian artery, for disarticulation and for amputation of the arm, and in conjunction with brief general narcosis, for the disarticulation of the arm with the shoulder girdle. Matas, at an early period, employed endoneural injections into the largest nerve-trunks for major operations on the extremities. Cushing (1902) advised cocainization ("blocking") of large nerve-trunks before cutting them, as they come in sight during an operation under general narcosis; this is to prevent shock, which, as Cushing showed, might occur even with general anesthesia when large nerve-trunks are divided.

Endoneural Injection in Nerves which Have Been Laid Bare During the Progress of an Operation with Local Anesthesia.—This procedure for regional anesthesia was recommended by Cushing in operations for inguinal hernia (1900). He taught us in these operations to search for and cocainize the iliohypogastric, the ilio-inguinal, and the genitocrural nerves. (See p. 1073.)

Where practicable, one may considerably prolong the anesthesia from an endoneural injection by immediately applying proximally an Esmarch bandage.

Nerve Degeneration Following Endoneural Injections.—v. Lier has examined microscopically the trunk of the sciatic nerve in rabbits after endoneural and perineural injections. Following endoneural injections of 1 per cent. cocain in distilled water or 1 per cent. eucain in 0.6 per cent. solution of sodium chlorid, a certain number of nerve-fibers were always found to have undergone fatty degeneration. Perineural injections of the same solutions around the nerves showed absolutely no degeneration. I have been unable to find any records of sensory or motor paralyses following a case of either endoneural or perineural injections of cocain or novocain.

From what has been said, it will be seen that in *pure cocain anesthesia* one should be able to avoid general cocain-poisoning by using

regional conduction anesthesia in the widest possible extent, and by employing for infiltration *weak solutions* (for example, Schleich, $\frac{1}{10}$ per cent. and weaker), enhancing their local effect by compressing the proximal veins either manually or with clamps, or by means of a stasis bandage. Other means to be employed are elevation at a right angle and cooling the entire infiltrated area with an ether spray. All these measures are to be taken before beginning the operation. In operating on the extremities it is best to use an Esmarch bandage during the entire operation.

Reclus, who has collected and published the results of over 7000 operations with cocain anesthesia, insists that even during the smallest operation with cocain anesthesia the patient must be in the *recumbent position*, and so remain for at least from twenty minutes to three hours after the operation. Restlessness, dizziness, and delirium are the first symptoms of general cocain-poisoning.

Cocain-adrenalin Anesthesia.—When ophthalmologists, rhinolaryngologists, and dentists in their use of suprarenal extract as a vasoconstrictor and hemostatic had discovered that it also to a high degree enhances the effect of local anesthetics, especially of cocain, H. Braun, in 1902, started a series of experiments with adrenalin which became epoch-making in the history of local anesthesia. The active principle in suprarenal extract is a very poisonous alkaloid, which was first produced in pure crystalline form by Parke, Davis and Co., and by them placed on the market under the name of adrenalin. The commercial preparation is composed of a solution of hydrochloric acid, made *in vacuo*, containing 1 : 1000 adrenalin. It must be kept in a dark room and should be hermetically sealed, as it is readily decomposed, in which case it first becomes faintly rose-colored, then more of a brownish-red and turbid. In surgery none but *absolutely colorless* and *entirely clear* solutions must be used. Several other firms are making similar preparations.

Suprarenal juice, suprarenal extract, and adrenalin effect, in incredibly small doses, a transitory *rise of the blood-pressure* caused by—(1) *direct increase in the heart's action*; (2) *contraction of the non-striped muscular fibers in the arteries and capillaries.* The effect upon the heart and the vessels is purely local, consequently peripheral. Läwen has demonstrated that, having accomplished its constricting effect upon the vessel, the adrenalin is then destroyed by the living vessel-wall. It is significant that the vessels in the various vascular regions are differently affected by adrenalin. Thus the vessels of the stomach, the intestines, and the bladder are affected to a less degree than are those of the integument, and *those of the lungs not at all.* After the injection, *ad modum* Schleich, into the skin or subcutaneous tissue, of adrenalin in a physiologic sodium chlorid solution 1: 600,000 or 1: 300,000 (which means one drop of Parke, Davis and Co.'s adrenalin 1: 1000, added to 20 or 10 cc. respectively of sodium chlorid solution, provided that the drops be of a size that 30 such drops are contained in 1 cc.), the capillary circulation will soon have ceased. On section,

the tissue is pale and watery. Nerves and vessels appear very prominently. There is only a slight bleeding from some of the larger arteries. In the venous lumina blood is stagnant, or they may be empty. The anemia will last for about one hour or longer. It is not necessary to infiltrate the operative field itself. It is sufficient to inject into the proximity, provided a somewhat more concentrated solution is being used, whereby even the larger arteries are made to contract.

Braun's investigations now showed that, *by adding adrenalin in the above small doses to isotonic solutions of sodium chlorid* in infiltration anesthesia, *the local anesthetic effect of cocain became very markedly enhanced and also prolonged.* Through its action as a vasoconstrictor the cocain to a certain, although very slight, extent increases the tissue-blanching power of the adrenalin. *Adrenalin is equally important for perineural and endoneural conduction anesthesia as for infiltration anesthesia.*

The reason why adrenalin so greatly augments and prolongs the paralyzing effect of the cocain upon the nerves and their end-organs must be that adrenalin, like freezing, a stasis bandage or an Esmarch bandage, temporarily arrests the circulation, and so, for an equally long time, "incarcerates the cocain," to adopt the expression of the pioneer, J. Leonard Corning. Braun's researches have also demonstrated that β-eucain and even, to a far greater extent, tropacocain, lessen the vasoconstricting effect of the adrenalin. For this reason adrenalin, in connection with β-eucain, has not at all the same effect as when added to cocain, and with tropacocain it is almost useless. Even stovain anesthesia is comparatively only slightly enhanced by adrenalin. *The anesthetizing power of novocain is, on the contrary, enormously increased by the addition of adrenalin.* The conclusion seems to be warranted then that a larger dose of cocain may be used if adrenalin be injected at the same time. Experiments on animals are, however, conflicting on this point, inasmuch as Sikemyer has found the general poisoning from cocain to be only delayed, but not lessened, by adrenalin. In my opinion cocain is so dangerous that it would seem most prudent to continue using it in the same small doses and in the same weak solutions with adrenalin as formerly without it. My dosage has been a total consumption of from 0.03 to 0.05 gm. of cocain in solutions of 1:100, 1:200, 1:400, 1:800, 1:1000, 1:10,000. The same is true of adrenalin as of cocain, viz., intravenous injections are enormously—it has been estimated forty times—more dangerous than subcutaneous injections, although also here the concentration of the solution is decisive, as I have, during several years, in cases of peritonitis and shock, many times injected very slowly into a vein from 8 to 10 drops of adrenalin (1:1000) in from ½ to 1 liter of a physiologic solution of sodium chlorid. Braun, in 1902, by experimenting upon himself, fixed the subcutaneous dose at 0.5 mgm.; that is, 0.5 cc. of adrenalin solution 1:1000. When he injected a little more than this dose he experienced, after a few minutes, constriction of the chest, palpitation of the heart, and increase of the pulse-rate, etc. For local

anesthesia injections of a solution of 1: 1000 are never used. Solutions of, at most, 1: 30,000, or perhaps occasionally 1: 15,000, are employed (which equals 1 or 2 drops of a 1: 1000 solution in 1 cc. of a solution of sodium chlorid), but more often from 1: 60,000 to 1: 150,000 for conduction anesthesia, and only from 1: 300,000 to 1: 600,000 for infiltration anesthesia.

The poisoning power of adrenalin is diminished with the degree of dilution. I therefore believe that Braun was perfectly right when he announced, in 1907, that one might safely employ 1 cc. or even a little more of adrenalin (1: 1000) in the dilutions which are to be considered as proper for local anesthesia.

Aside from its toxicity, one has every reason to be careful in the use of adrenalin for fear of *secondary hemorrhage.* In solutions stronger than 1: 300,000, 1: 150,000, adrenalin exerts a constricting effect even on larger arteries, *e. g.*, the arteries of the fingers. These do not begin to bleed until the adrenalin anemia has lessened. If the wound has been sutured, a hematoma will form; if it be open and without a firm packing, *e. g.*, in the nose, a free secondary hemorrhage will result. After an adrenalin anemia the circulation returns gradually to the normal, with no intermediary stage of vascular dilatation, as after an Esmarch bandage. Every secondary hemorrhage following the use of adrenalin is, therefore, due to neglect to ligate or tampon because there was no bleeding at the time of the operation.

It cannot be gainsaid that more than necessarily concentrated solutions of adrenalin may injure the nutrition of the tissues, and thereby the healing, although conclusive observations on this point are as yet lacking.

In persons with arteriosclerosis one should be still more careful in the use of adrenalin, because it raises the blood-pressure.

Braun has lately tested two preparations: *synthetic suprarenin* and *arterenin.* Both these products are placed on the market in hydrochloric acid solutions, 1: 1000, which are not more stable than the natural adrenalin solutions, and must, therefore, be used only when absolutely clear and colorless. Their local action is identical with that of natural adrenalin. But Braun has also tested a third preparation, called *homorenon.* It is a hydrochlorate, crystalline, very soluble in water, stable, and can be boiled. His investigation showed homorenon to be fifty times less effective, but also generally fifty times less poisonous, than adrenalin. A 5 per cent. watery solution of homorenon corresponds, therefore, to a 1: 1000 solution of natural adrenalin. Solutions of homorenon neither irritate nor injure the tissues. Braun, therefore, expresses the opinion that *homorenon* is the preparation of choice for the present. With homorenon in powder or tablet form we would be able, by boiling, to prepare our own sterile watery solutions.

Novocain.—Novocain was discovered by Einhorn. It is soluble in water 1: 1. The solution is of neutral reaction. In watery solution it is precipitated by free and carbonated alkalis. Consequently avoid alkaline glass; do not boil syringes and needles in soda solution, but in

pure distilled water. The watery solution will stand boiling and is stable, even though it be kept exposed to the air. Biberfeld has made a pharmacologic study of novocain. Administered subcutaneously, it produces weaker toxic effects than any hitherto known local anesthetic. It has no peripheral effect on the vessels. Injected intravenously it causes a fall of the blood-pressure and the respiration becomes slow and superficial. The lowering of the blood-pressure is due to its action on the vasomotor center. On the heart it seems to exert no influence.

Braun tested the value of novocain as a local anesthetic in 1905, and Biberfeld found that it may be injected in and beneath the skin, even in the strength of a 5 per cent. solution, without causing the slightest pain and without in the least injuring the tissues.

Braun found that novocain is a powerful but fleeting local anesthetic, *of no practical utility except in conjunction with adrenalin.* In a concentration twice that of cocain and combined with adrenalin, novocain may take the place of cocain everywhere in terminal and conduction anesthesia. He had not seen any symptoms of poisoning even with the use of more than 0.4 to 0.5 gm. of novocain. In 1907 he stated that novocain-suprarenin anesthesia in his clinic has entirely displaced the cocain-suprarenin anesthesia.

From my published writings it is apparent that it was with great enthusiasm I at one time adopted Schleich's method, which I, however, abandoned after I had become acquainted with the *cocain-adrenalin anesthesia,* which, in my experience, has been uniformly successful, and to which I remained faithful even after trying β-eucain, acoin, and stovain. Not even the results, which my friend Arthur E. Barker, *with his excellent technic,* has been able to announce with the use of β-eucain anesthesia, seem to me to surpass those obtained with cocain-adrenalin anesthesia. Following Braun's announcement about novocain, I employed this agent at Christmas time, 1905, and thenceforth novocain-adrenalin anesthesia has also in my clinic completely displaced cocain-adrenalin solutions, with the exception of occasional cases of anesthesia of mucous membranes by applications upon the surface of cocain-adrenalin solutions. With novocain one need not anxiously count the milligrams, and the more thorough infiltration of the tissues which thus becomes possible will in many instances produce a more complete analgesia. We have injected over 0.60 gm. novocain and have observed no ill effects therefrom.

Technic of Local Anesthesia.—Indications.—Local anesthesia should be employed whenever it is possible with its aid to operate painlessly. It is, however, in most cases more inconvenient to the surgeon and requires a longer time to operate with local anesthesia than under general narcosis. Notwithstanding this it should be resorted to, especially when the general condition of the patient, *e. g.,* old age, marked anemia, or definite organic disease, renders general narcosis more than ordinarily perilous. External conditions also are often of a decisive consequence; above all, whether or not the surgeon has the advantage of having at his disposal the services of an expert anesthetizer. Because

of the unequal distribution of the sense of pain within the tissues and organs it is often possible to perform large parts of an operation painlessly without using either local or general anesthesia. This is particularly true of operations of the abdomen, but also of certain operations on the osseous system, etc. In many cases one may thus, by a combination of local anesthesia, morphin subcutaneously, and a brief ether narcosis, perform the severest operations painlessly, and, as to the narcosis, without danger. Here the opportunities for individualizing according to the demands of each particular patient are abundant. For the healing of wounds after certain operations, *e. g.*, radical operations for hernia, it is a great advantage that with local anesthesia the patients are able to remain quiet and that, as a rule, they do not vomit.

Local anesthesia enables the unassisted surgeon successfully to practice all kinds of minor surgery, as operations for furuncles, carbuncles, whitlow, phlegmonous thecitis, ingrown nails, small tumors, "precancerous" ulcers, surgery of accidents, etc. Cancer of the lip and the tongue, rodent ulcer, and incipient lupus may be extirpated even before the dreaded diagnosis is macroscopically or perhaps microscopically certain. Every medical student should learn to perform the most important emergency operations with local anesthesia, viz., difficult catheterization, herniotomy, tracheotomy, thoracotomy, cystotomy, extraction of teeth.

Local anesthesia will cause the surgeon to operate with anatomic conservatism and accuracy, and to avoid, as a rule, blunt dissection. It makes of him an anatomist, and especially a nerve-anatomist.

Preparations for the Operation.—When local anesthesia alone will suffice, the patient is allowed for breakfast coffee, eggs, and the like. If, however, ether narcosis is believed to be needed to help the patient over the stages in the operation in which local anesthesia may be insufficient, he should be fasting. In this event, 0.01 to 0.015 gm. of morphin should be given subcutaneously preceding the injections of novocain, *i. e.*, at least half an hour before the administration of ether. In other cases the same dose of morphin is given only if the patient complains of being tired. It is evident that patients not requiring general narcosis may be given something good to eat or drink during the operation, and it also goes without saying that *silence,* as well as other disciplinary rules of the operating-room, must be scrupulously observed, both by assistants and the surgeon.

Syringes, Solutions, Technic.—Recording syringes with metal plunger, now in general use, are suitable. For stronger solutions syringes holding 1 or 2 cc., for weaker solutions those holding 5 or 10 cc., are employed. It is well to have an assortment of needles differing in length and thickness. For the skin the needles must be very thin and sharp. Intracutaneous injections—wheal formation—may then be performed almost painlessly. Every injection in the skin or the mucous membrane is started by producing a wheal. Thrusting the needle through these successively is thereafter painless. The needle-point should have a short bevel, almost at right angle in many cases.

Schleich employed three cocain solutions: (1) 1: 500 = 0.2 per cent.; (2) 1: 1000 = 0.1 per cent.; (3) 1: 10,000 = 0.01 per cent. I formerly used $\frac{1}{10}$ to 1 per cent. cocain in physiologic solution of sodium chlorid, with adrenalin in the same proportions as for novocain solutions. Like Braun, I now employ four novocain solutions:

No. 1.	Novocain	0.25	
	Physiologic saline solution	100	
	Adrenalin (1: 1000) or homorenon (4 per cent.).	5	drops.
No. 2.	Novocain	0.25	
	Physiologic saline solution	50.0	
	Adrenalin (1: 1000) or homorenon (4 per cent.).	5	drops.
No. 3.	Novocain	0.1	
	Physiologic saline solution	10.0	
	Adrenalin (1: 1000) or homorenon (4 per cent.).	2	drops.
No. 4.	Novocain	0.1	
	Physiologic saline solution	5.0	
	Adrenalin (1: 1000) or homorenon (4 per cent.).	5	drops.

Hitherto I have only had opportunity to use Parke, Davis and Co.'s adrenalin (1: 1000). Braun uses for solutions No. 3 and 4 twice as much adrenalin as I do, *i. e.*, 5 drops for No. 3 and 10 drops for No. 4. For solution No. 1 I often use 1 drop adrenalin to 10 cc. Solution No. 2 diluted with an equal amount of saline solution gives No. 1, and solution No. 4 gives in the same way No. 3. Solution No. 4 (2 per cent. novocain) I have so far only used for injection in the gums and periosteum for the extraction of teeth. Braun says that because of the harmlessness of novocain he now, as a rule, uses solutions No. 2 and No. 4. It is plain that, for perineural injections, it is in certain cases of great advantage that the anesthetizing solution possess a considerable power for penetration. In case of perineural injection, where it is difficult to inject the solution just closely around the nerve, or where the injection is intended for one of the larger nerves with a thick sheath, I shall continue to use No. 4. But for endoneural injections I shall employ No. 2 and No. 3, the former solution for thinner, the latter solution for thicker nerves, until it has been proved by ample experience that a 2 per cent. solution of novocain is entirely harmless, even in endoneural injections. Only in the case of an endoneural injection for amputation, when the nerve is to be severed, would I possibly use solution No. 4.

On their emergence from the subdural space the nerves, as is well known, become invested with a sheath of dura mater. Where the nerve-trunks are the thickest, there also the nerve-sheaths are the thickest and the most fibrous, growing thinner as the nerves approach their terminal distribution. The terminal branches have no sheaths. From this it follows that an organ possessing only terminal nerve-branches and nerve-endings, *i. e.*, the skin, is the one which is most easily rendered insensitive. Next in order comes the periosteum, and thereafter perhaps the parietal serosa of the thorax and the abdomen. The only tissue which it is possible to infiltrate, *i. e.*, to so fill up with the solution that every nerve-cell becomes immersed in it, is the skin.

This is accomplished by the production of wheals. The skin is thus rendered immediately insensitive, even with cocain solutions as weak as 1: 1000 to 1: 20,000, and with novocain 1: 1000. For infiltration of the skin I employ $\frac{1}{8}$ per cent. novocain. Next after the skin the periosteum is the tissue which it is easiest to infiltrate. Of major operations, it is easiest to produce local anesthesia[1] (infiltration anesthesia) for a laparotomy in the midline, and then especially in a case of wide diastasis between the recti muscles. When, with a very fine and sharp needle, the required number of wheals has been produced so as to enable one painlessly to thrust the needle through the skin, the injections of novocain-adrenalin solution No. 1 are made (always while pushing forward or withdrawing the needle), first subserously (do not perforate the peritoneum), then in the linea alba, and finally subcutaneously. A half-hour after the injection has been finished, perhaps sooner, the anesthesia is complete. In every laparotomy the anesthesia should be made to extend beyond the length of the intended incision. If the subserous connective tissue at the sides of the incision be not thoroughly soaked in the solution, one should, with the aid of a controlling finger in the peritoneal cavity, inject $\frac{1}{8}$ or $\frac{1}{4}$ per cent. novocain-adrenalin subserously in all directions around the incision. By so doing it will be possible to use retractors and also, even after a prolonged operation, to suture the peritoneum without causing any pain. A little practice will enable one to produce anesthesia for an incision through the sheath of the rectus. Personally, in the majority of my cases of median laparotomy, I use the median incision through the sheath of the rectus, as described by me. An injection of solution No. 1 is first made in the posterior surface of the rectus, then beneath the anterior sheath of the rectus, and finally subcutaneously in one or two layers, close to the aponeurosis and close to the integument, after which one should wait for half an hour. Above the semilunar folds of Douglas it often happens that one is unsuccessful in entering the subserous connective tissue. The rectus having first been pulled outward, a short-beveled needle is pushed through the posterior sheath of the rectus, and thus within a couple of minutes the subserous connective tissue may be filled with $\frac{1}{4}$ or $\frac{1}{8}$ per cent. novocain-adrenalin, making the parietal peritoneum insensitive. It is not necessary to infiltrate the integument. During the time of waiting after the injection has been completed the integumentary nerves are being paralyzed in their passage through the subcutaneous tissue. The nerves being thinnest in and around the midline of the thorax and the abdomen, anteriorly as well as posteriorly, anesthesia occurs in these situations sooner than in other parts of the body. It is, therefore, in these operations unnecessary to wait half an hour. In case of imminent danger, then also the skin is immediately infiltrated for the entire length of the incision, or, preferably, it is frozen with ethyl chlorid and the operation begun at once.

In all major operations, however, the rule should be observed not to begin the operation until half an hour after the last injection. The larger

[1] Local anesthesia in a narrow sense; see p. 1046.

the nerves which are passing in the fasciæ between the muscles, and the denser their sheaths, the longer will be the time required for the novocain to penetrate into the nerve-fibers. In my clinic we are, therefore, in the habit of removing the patients wrapped in sterile sheets back into their beds after the disinfection. Then we proceed with the injection in all cases where this is practicable, and the patient is allowed to remain in bed for half an hour; then he is taken to the operating-room. In those cases of infiltration anesthesia when one aims at getting the novocain around larger nerve-trunks, *e. g.*, deep into the lumbar regions, we employ solution No. 2 (½ per cent.). For perineural injections solution No. 3 (1 per cent.) or No. 4 (2 per cent.) are employed. In these cases, too, it is well to wait for half an hour.

In many operations it is possible, in the manner described, to fill the tissues from the depth to the surface with the solutions No. 1 and No. 2. In other cases one will have to do a circular or semicircular injection. Proceeding from one or more wheals in the skin, a shell of tissue, as it were, around the entire or one half (see below) of the operative field, is filled with No. 1 or No. 2. This procedure becomes necessary in malignant tumors or in infectious maladies. In either event the injections should be made beyond the area of infected lymph-channels. In furuncles, abscesses, etc., one cannot inject within the inflamed area, for the additional reason that such injections would be painful.

In planning a local anesthesia one must in every instance have a clear conception of the topographic anatomy, and especially of the nerve anatomy, of the region, and also how one intends to operate. Then one must consider what in that particular case may be gained by endoneural or perineural injections, by infiltration of the entire operative field, or by a circular injection. One must decide whether the circular injection needs to extend around the entire operative field, or whether it is sufficient to inject in a straight line, ——, an angular line, Λ, or in a semicircle, ⌒, on one or two sides.

In order more plainly to illustrate the choice of methods, I will pass in review the various regions of the body. I presuppose that the reader has for his guide a good atlas or anatomy of the nerves.

The Head.—The cranium and its soft parts receive their nerves from the three branches of the trigeminus and from the cervical plexus.

The most important of these nerves are the frontal, the supra-orbital, the auriculotemporal, the auricularis magnus, and the occipitalis minor and major. One should bear in mind the locations of these nerves and the points where they penetrate the muscular fasciæ and become subcutaneous. It should be clearly understood that they innervate all the soft parts of the cranium from the periosteum to the skin. It is plain that, by injections of solution No. 1 in periosteum, muscles, and subcutaneous connective tissue around the head at a level with the supra-orbital arch, and by additional injections of No. 3 perineurally around the larger nerves at the points where they emerge through the muscular fasciæ, all the soft parts within this circumference

will be rendered insensitive. The bone has no sensation, neither has the dura mater, over the convexity of the brain, but it becomes sensitive, especially to traction, on approaching the zygomatic arch. Even beneath the mastoid portion the dura mater is, according to my observations, insensitive. The remaining portion of the dura may have sensation. It receives nerves from all the three branches of the trigeminus and from the vagus.[1] I am inclined to believe it would be possible to anesthetize a portion of the dura mater at the base of the brain through branches of the trigeminus accompanying the middle meningeal artery. One ought, therefore, to try and inject slowly, say, solution No. 2, with a blunt needle, between the dura and the bone above the zygomatic arch, along one of the branches of said artery.

For operations on the top of the vertex anesthesia, therefore, cannot be produced, except by a circular injection around the entire operative field. To operate in the middle of the forehead the injection is made in a line above the orbits, and for the middle of the occiput in a line at a level with the origin of the trapezius, always aiming to inject especially around the points where the nerves emerge from their deep canals and from under the muscular fasciæ. To operate in the temporal region one will have to make at least a semicircular injection, and take special care sufficiently to infiltrate the periosteum. The mastoid portion and its cells may be widely opened, and the entire mastoid process extirpated, provided that all the periosteum within the field of the operation, consequently also that on the posterior (internal) surface of the mastoid process, be carefully infiltrated, and, in addition, solution No. 2 be injected between the auditory canal and the bone, raising the periosteum from the mastoid portion. The presence of the adrenalin in the solutions renders the operations less bloody.

The Face.—In all plastic operations about the face local or regional anesthesia may be employed. Matas has performed double resection of the superior maxilla under cocain anesthesia of the second division of the trigeminus. He inserted the needle through the sphenomaxillary fossa into the sphenopalatine fossa. By a proper combination of morphin subcutaneously with local and regional injections of novocain-adrenalin it is possible, under a very superficial ether narcosis, to perform painlessly the most extensive operations about the face.

Extraction of Teeth.—An injection of No. 3 or No. 4 is made beneath the mucous membrane and the periosteum on both sides of the alveolar process. In the upper jaws one should remember that before they enter the bone the posterior dental nerves are found beneath the mucous membrane on the posterior surface of the superior maxilla. The lower jaw, including the teeth and periosteum between the two mental foramina, receives branches from the inferior dental nerves of both sides. Here the bone may be made perfectly insensible, *e. g.*, temporary resection by the injection of No. 3 or No. 4 in the periosteum

[1] Poirier et Charpy, Traite d'Anatomie humaine, T. viii., p. 112, and their figures (428, 447, and 448).

around the jaw. For painless extraction of the posterior molars in the lower jaw it is in many instances sufficient to inject No. 4 beneath the mucous membrane and the periosteum. In order that the teeth and the bone be surely anesthetized it will be necessary to make a perineural injection around the inferior dental nerve as it enters the inferior dental foramen. The needle is inserted 1 cm. above the upper surface of the third molar, and then, guided by the feeling of the bone, is carried to the outer side of the lingula at the aperture of the inferior dental canal. Here a generous injection of No. 4 is made. One may count upon the solution spreading also to the lingual nerve. In order to anesthetize the lingual nerve alone, an injection of solution No. 3 should be made beneath the mucous membrane of the floor of the mouth at the inner side of the lower jaw. The glossopharyngeal nerve is to be found in the posterior lateral portion of the tongue internally to the styloglossus muscle.

The Neck.—For operations in the median line of the neck, *e. g.*, tracheotomy and laryngotomy, it is easy to produce complete anesthesia by infiltration. In thyroidectomy, the skin, the subcutaneous tissue, and partly the middle layer of the cervical fascia may be rendered insensitive, but to deliver the gland into the incision or otherwise to stretch upon the parts, *e. g.*, in ligating the superior thyroid artery, is always attended by pain. The thyroid gland itself has no sensation. A majority of thyroidectomies may be performed with local anesthesia. It is, however, necessary to select the cases, as some patients will undoubtedly do better under local anesthesia combined with general narcosis; others under ether narcosis alone.

In the majority of operations for cervical lymphomata local anesthesia is very useful. The nerves (auricularis magnus, superficialis colli, and the supraclavicular branches) are located at the points where they emerge beneath the posterior border of the sternomastoid at about its middle. Here one should make generous injections of solution No. 3. Should it be apparent at the outset that it will be necessary to sacrifice one or two of these nerves, then one might as well begin the operation with that. Even after a perineural injection around the cervical plexus has been made, one will always have to infiltrate the subcutaneous tissue at the lower jaw and at the mastoid process around the insertion of the sternomastoid if it should be necessary to turn this muscle downward. Superficially situated lymphomata may be operated upon absolutely painlessly with perineural and local anesthesia. For deep-seated lymphomata the need of ether may be greatly limited, although it cannot be entirely dispensed with in other than very patient individuals.

The Upper Extremities.—Here there is scarcely an operation that cannot be performed under regional or local anesthesia. It is to be remembered that the bone-substance, the bone-marrow, and the cartilages are not sensitive, but that the periosteum, the perichondrium, and the synovial articular membranes are very sensitive. The periosteum of the shaft of the humerus receives its nervous supply from

the radial and the musculocutaneous nerves, and that of the shaft of the radius and the ulna from the median nerve. The elbow-joint, as well as the wrist- and carpal joints, receive branches from all three great nerves, viz., the median, the ulnar, and the radial.

For all operations on the skin and the subcutaneous tissue one should always first consider where the subcutaneous nerves contained within the field of operation penetrate the deep fascia, in order to determine whether perineural injections alone may be sufficient or whether they should be used in conjunction with local anesthesia (infiltration). For major operations about the hand, resections of the wrist-joint, amputations, etc., of the forearm, resections of the elbow-joint, perineural and endoneural injections may be employed. I have, for example, recently performed three painless resections of the elbow-joint after an injection of solution No. 3 into each nerve, having first—under local anesthesia—laid bare all the nerves at a level with the tendon of the latissimus dorsi.

To operate upon a severe case of phlegmonous thecitis extending up toward the elbow, under local anesthesia, the median, the ulnar, and the internal cutaneous nerves are laid bare at the middle of the upper arm, and then solution No. 3. is injected into them. With the same solution, perineural and local injections are also made laterally to the tendon of the biceps, in order to reach the cutaneous branches of the musculocutaneous and the radial nerves.

In my experience it is never painful to thrust the thin, sharp point of a needle into a healthy nerve and *slowly* inject an anesthetic solution, provided the nerve is held *slack*, so that the injection may be made into it without the slightest traction upon its fibers. An injection into a nerve that is being stretched is painful. In case a lymphangitis has extended to the nerve-sheath, endoneural injections are certainly always very painful. If, for example, one should want to disarticulate the third finger and amputate its metacarpal bone, a perineural injection of No. 3 or No. 4 is made around the ulnar nerve, behind the internal condyle of the humerus, and around the cutaneous branches of the radial nerve, above the styloid process of the radius, and also an endoneural injection into the median nerve above the wrist, or, in case of a lymphangitis extending from the hand into the forearm, in the upper arm. The median and the ulnar nerves may also be rendered insensitive by a pericutaneous perineural injection around them just above the wrist.

For operations about the fingers an injection of solution No. 2 or 3 should be made around a basal phalanx, taking care to place the most of the solution around the four nerves of the fingers. In operations at a level with the metacarpophalangeal articulations solution No. 3 should be injected in a transverse band subfascially and subcutaneously in the palm and in the dorsum of the hand.

For an amputation of the upper arm, local anesthesia of the periosteum, the muscles, and their intervening spaces of connective tissue, the subcutaneous tissue, and the integument may be produced by solu-

tion No. 1. In the course of the operation, as the large nerves are laid bare, each should receive an injection of solution No. 3 or 4. Resection of the shoulder-joint is best done under general narcosis or under combined local and general anesthesia. For disarticulation of the entire arm, or of the arm with the shoulder-girdle, it is always best to start with laying bare, under local anesthesia, the brachial plexus, and to inject No. 3 or 4 into each of its nerve-trunks, making at the same time a temporary compression upon the subclavian artery (Crile). To disarticulate the arm alone there is then no need of narcosis. If, also, the shoulder-girdle is to be extirpated, then at an abundantly long time before the operation local anesthesia should be produced along the greater extent of the skin incision. During the operation a light ether narcosis is produced when the scapular muscles are to be divided. The rest of the operation is painless without narcosis. The third portion of the subclavian or the axillary vessels and nerves can also be operated upon painlessly.

The Thorax.—One should remember that the sternum, the ribs, and the costal cartilages have no sensation after the periosteum and the perichondrium have been scraped off and that the parietal pleura and pericardium have a very highly developed sensation. The connective tissue behind the costal cartilages in front of the pericardium is, according to my observations, very sensitive to pain, which well accords with the researches of Ramström. He found a continuous chain of rich anastomosis between the intercostal nerves in the triangularis sterni muscle. Probably all the connective tissue in the mediastinum is endowed with the sense of pain (the phrenic and the intercostal nerves). The areas of distribution of the intercostal nerves within the thoracic wall overlap one another, so that, for example, the area supplied by the third nerve, schematically viewed, borders everywhere upon that supplied by the fifth nerve, the conjoint area of distribution of both of these nerves consequently completely covering that of the fourth nerve. One has, therefore, at every point of the thorax to take into account an innervation from at least two nerves. Every rib is innervated both from the intercostal nerve lying above it and from that running along its lower border.

It is very easy to perform pleurotomy and pericardiotomy painlessly. To this end it is only necessary to infiltrate with solution No. 1 the tissues from the pleura or pericardium out to the integument. To resect a rib it is best liberally to infiltrate the periosteum on the outer surface of the rib, the muscles, and the subcutaneous tissue with No 1 for the entire length of the intended incision. When, in the course of the operation, the periosteum has been loosened from the outer surface of the rib, solution No. 3 should then be injected along the lower and upper border of the rib to the full length of the incision, and also some distance behind it, *i. e.*, proximally to the incision. One will then soon be able painlessly to detach the periosteum from the posterior surface of the rib, etc.

If two or more ribs are to be resected, it is best to make a perineural

injection around three or more intercostal nerves. At the angle of the rib the intercostal nerves are close to the lower border of each rib. The nerve, the artery, and the vein are enclosed in a sheath derived from the internal intercostal muscle between the two ribs in question. The internal intercostal muscles begin, as we know, at the angles of the ribs, and extend forward to the sternum. In this muscular sheath, lodged in a groove on the inner surface of the rib, the vein is highest, then the artery, while the nerve is at the bottom, lying just on the inner side of the lower border. More anteriorly, on the thoracic wall, the ribs become gradually altered in shape. The sulci are obliterated and disappear at the middle of the ribs. Simultaneously, there occurs a downward displacement of the vein, artery, and nerve, so that they are found from above downward in the order named in the middle of the costal interspace, and now running between the internal and external intercostal muscles. (Compare Fig. 397 in Poirier's and Charpy's "Anatomie," T. i, and Figs. 579 and 580 in T. iii.) To do a perineural injection a long needle with a short beveled point is introduced from behind forward, parallel to a rib, the operator aiming to reach the lower border just in front of the angle. The point of the needle is now lowered just enough to pass under the border of the rib to its inner surface. Here the injection is made while the needle is being pushed forward. It is difficult to reach the nerve with certainty, and for this reason solution No. 4 should be used. The twelfth intercostal nerve varies so much in its location that it is scarcely possible to reach it in this manner. Sellheim has, therefore, developed a method by which he has succeeded in anesthetizing this nerve and the upper lumbar nerves through percutaneous injections of cocain around the nerves in the intervertebral foramina. It is necessary, first, to practice on the cadaver with injections of, for example, India ink. Should these perineural injections of Sellheim's prove successful, and should they also be found to be harmless, causing no injury to the nerves and being followed by no dangerous diffusion of the novocain-adrenalin solution into the subarachnoid space, then they ought to become of great importance and seriously to compete with spinal anesthesia in a class of cases in which the results of that anesthesia are very uncertain. Within the area of those nerves which were reached by the injections a complete anesthesia of very long duration would be produced over the entire one-half of the abdomen (for appendicitis, kidney, ureter, gall-bladder, and gall-duct operations, etc.). Animal experiments ought to be made in order to decide this.

In doing a plastic operation posteriorly on the thoracic wall it is best to make the incision in such a direction as to lay bare, under local anesthesia, one intercostal nerve after another, and to inject each nerve separately. The previously described percutaneous perineural injections at the angles of the ribs do not produce anesthesia of the integument and of the muscles of the back from the midline to far beyond the costal angles, as those parts are innervated by the posterior divisions of the dorsal nerves. These, from which the posterior cutaneous

branches are derived, are given off from the dorsal nerves in the intervertebral spaces.

When hesitating between local and regional anesthesia about the thorax, one has always to recollect: (1) the origin and distribution of the perforating branches; (2) the numerous nerves derived from the brachial and cervical plexuses. (See Figs. 539, 540, and 581 in Poirier's and Charpy's "Anatomie," T. iii.)

In 1907 I twice performed *laminectomy* in spinal tuberculosis under local anesthesia. While the patients were in bed I injected solution No. 1 from the deeper tissues successively outward toward the surface. First, with the needle, I followed carefully the posterior surface of each arch, in order to anesthetize the periosteum of the arches, and then injected the muscles and the subcutaneous tissue. After a half-hour the patients were removed to the operating-table. The first operation was absolutely painless. In this case the arches were widely tuberculous, and a cheesy mass filled the spinal canal, pressing upon the dura mater. In the second case the arches were healthy and the periosteum on the anterior surface of the arches retained its sensation. In a similar operation in the future it ought to be easy after laying bare the arches to inject solution No. 3 between them, thus rendering the anterior periosteum and the remaining connective tissue behind the dura insensible.

The Mamma.—Abscesses may be opened and benign tumors extirpated under local anesthesia. In operations for malignant tumors of the breast local anesthesia is not suitable. The circumstances might, however, be such that one will have to try it—*e. g.*, in a case of serious disease of the heart and lungs.

The Abdominal Wall.—One has to remember, as in the case of the thoracic wall, that the cutaneous nerves are derived from the posterior, middle, and anterior perforating nerves, and that the areas of adjoining sensory nerves overlap each other. When I first wrote on the sensibility of the abdominal cavity (1901), works on anatomy scarcely contained any information about the nerves of the parietal peritoneum beyond the statement that the phrenic nerve sent a branch through the slit between the sternal and the costal portion of the diaphragm, and that it supplied the parietal peritoneum with sensory nerves as low down as the navel (Luschka). Through my researches it became established that the parietal peritoneum is not only very sensitive to pain, but also that it is undoubtedly innervated from the nearest intercostal, lumbar, and sacral nerves, because in a lateral laparotomy, either in the upper or in the lower part of the abdominal wall, when two or more of the large nerves had been cocainized, or when all the nerves had been severed, the parietal peritoneum medially to the incision was always found to be insensible, at least that part which corresponded to the middle of the incision. Ramström (1904–1906) has given a complete account of the innervation of the diaphragm and of the subserosa and serosa of the anterior abdominal wall. It is necessary to be acquainted with these researches in order suc-

cessfully to produce local anesthesia of the abdominal wall, and not to expect too much from the subarachnoid anesthesia. Ramström has shown that the phrenic nerve alone is the motor nerve for the entire diaphragm, and that it gives off sensory branches to its entire pleural investment, and also to its entire peritoneal investment, excepting at the rim, where both the pleura and the peritoneum receive sensory branches from the fifth to the twelfth intercostal nerves. He never succeeded in tracing these nerve-filaments farther into the diaphragmatic peritoneum than to a point corresponding to the outer third of the distance between the thoraco-abdominal wall and the central tendon; and he did not find a single filament from the phrenic nerve running over the anterior abdominal wall.

Ramström did not ascertain whence the connective tissue, the subserosa, and the serosa in front of the dorsolumbar portion (the crura) of the diaphragm receive their sensory nerves. Until this is known, one has a right to presume that the phrenic nerves, as well as the intercostal and lumbar nerves, give off sensory branches to this part of the abdominal wall.

These investigations of Ramström on the innervation of the diaphragm lead to the conclusion that in subarachnoid anesthesia we should not count upon being able to exert traction upon the liver or turn it over, or stretch upon the cardiac orifice of the stomach or the esophagus, etc., without causing pain, unless the cutaneous anesthesia extends up on the neck at a level with the origin of the phrenic nerve in the spinal cord, in which event a respiratory failure is to be feared.

From Ramström's descriptions and figures we find that the main trunks of the abdominal nerves run in the abdominal wall upon the transversalis muscle, between it and the internal oblique. Far to each side, between the ribs, the lateral perforating nerves are given off, each of which is composed of a large muscular branch to the external oblique muscle, running mediocaudad in the direction of the muscle-fibers and of large cutaneous branches. Upon and within the transversalis muscle all the abdominal nerves (the intercostal, iliohypogastric, ilio-inguinal) are united by very numerous anastomoses between each two adjacent nerves. It is from these anastomoses that the majority of the peritoneal nerves are derived. They penetrate into the subserosa, either through the transversalis itself or, in a much greater number, through the aponeurosis of that muscle in the vicinity of the linea semilunaris. Hence the peritoneal nerves generally pursue a course in a medial or a mediocephalad direction until they approach the vicinity of the linea alba, when they often turn around in a direction purely cephalad or purely caudad. The peritoneal nerves are very numerous in the anterior abdominal wall. They form a deep-seated plexus of coarser filaments in the subserosa adjoining the sheath of the rectus and the rectus muscle, and a superficial plexus of fine filaments running just beneath the peritoneal epithelium. In the epigastrium the peritoneum is innervated from the sixth to the eighth, immediately above the navel from the tenth, immediately

below the navel from the tenth and eleventh, and farther down from the eleventh and twelfth intercostal nerves, while the recti muscles above the navel receive no branches from the tenth intercostal nerve. All the filaments from this nerve go to the rectus muscle below the navel. The filaments from the eleventh and twelfth intercostal nerves to the recti muscles, extending down as far as the symphysis, pursue an almost purely caudad (vertical) course in these muscles. On seeing the rich nerve plexuses as they appear in Ramström's illustrations in the subserosa and the serosa from the linea semilunaris to the linea alba, and the numerous nerve-filaments extending over a large part or over the whole of this area, one will readily understand why the parietal serosa is so sensitive.

To obtain complete loss of sensation of the serosa in the epigastrium with subarachnoid anesthesia necessitates a paralysis of the sensory nerve-roots in the subarachnoid space, up to a level with the spinous process of the third vertebra.

I have previously (p. 1063) described the technic of local anesthesia for abdominal section in the linea alba and in the medial portion of the sheath of the rectus. For abdominal section in the lateral portion of the sheath of the rectus solution No. 1 is likewise injected through the rectus muscle to its posterior surface, and also beneath the anterior lamella in front of the muscle. One should also make an effort to deposit a stratum of No. 1 around the lateral border of the rectus. An injection is therafter made into the subcutaneous connective tissue, partly immediately over the anterior sheath of the rectus and partly close to the skin. In lateral incision of the sheath of the rectus, as I have described it, one should attempt to save the nerves going to the rectus. They come into view as soon as the muscle is drawn inward. In case these nerves be not deadened, inject a few drops of No. 2 in each nerve as far outward (proximally) as possible, and then separate the nerves upward or downward, all according to their course. The parietal peritoneum between the nerves will then be rendered insensible. In operations above the semilunar fold of Douglas it will be necessary in most cases to make an injection of No. 1 or of $\frac{1}{2}$ per cent. novocain-adrenalin between the posterior sheath of the rectus and the peritoneum after the rectus has been drawn inward.

In oblique or transverse incisions laterally to the sheath of the rectus one should bear in mind that the main nerve-trunks, together with richly developed anastomoses, are situated on the external surface of the transversalis. One should, therefore, attempt to deposit a liberal amount of No. 1 or No. 2 between the transversalis and the internal oblique laterally (*i. e.*, proximally) to the intended incision, and upward and downward in relation to its lateral (posterior) end. It is consequently intended with this injection to reach the abdominal nerves and their anastomoses as centrally as possible; in other words, to produce a regional anesthesia. But as this is rather uncertain, the injection of No. 1 between the transversalis and the internal oblique is continued forward to the end of the incision. One should never attempt to deposit the solu-

tion within the subserosa, because in so doing one might perforate the peritoneum and wound the intestines or other viscera. A. E. Barker uses for deep injections of the abdominal wall blunt needles with perforations at the sides. Having done the injections between the transversalis and the internal oblique, one has then to inject No. 1 into the external oblique, following the direction of its fibers to the full length of the intended incision, and likewise into the subcutaneous tissue parallel with the direction of the fibers of the integument, because the nerves which supply the external oblique and the skin are given off so far toward the back that it is not likely they have been reached by the solution injected between the two deep abdominal muscles. Then wait for at least one-half hour. In case the injections have succeeded well, even the parietal peritoneum will now have been made insensible. If not, another injection of No. 1 is made after the transversalis has been divided. If, after opening the abdomen, it is found that the serosa is not insensible to a sufficiently large extent around the wound, then, as previously described, injections are to be made in the subserosa all around the wound, under the control of a finger in the abdominal cavity. Every attempt at traction upon attachments of mesenteries and adhesions to the abdominal wall being painful, comparatively few abdominal operations may be done under local anesthesia alone. I mention among them exploratory laparotomies for cancer of the stomach, etc., for ascites, Talma's operation, operation for tuberculous peritonitis in simple cases, gastrostomies, cholecystostomies, if the gall-bladder be easily accessible, enterostomies, typhlostomies, operations for fistulas of the stomach and intestines, simple extirpations of the appendix, simple cases of volvulus, simple cases of subserous myomata and of pedunculated ovarian tumors, encapsulated, purulent exudates, even subphrenic ones, when easily accessible. In many instances it is possible to perform important operations painlessly by combining local anesthesia with, for example, ether narcosis, as in intestinal resections for stenosis or tumors. There is then no need of narcosis for the resection and suturing of the intestine, but only for the pain incident to examination of the abdominal cavity and traction upon the intestine. During the decade of 1890–99 I have operated upon a large number of incarcerated and many reducible hernias under local anesthesia, and since Cushing, in 1900, published his method of local and regional anesthesia in operations for inguinal hernia, I have made it a rule to operate upon all varieties of hernia under local anesthesia.

Inguinal Hernia.—The region of these hernias is innervated from the iliohypogastric, ilio-inguinal, and genitocrural nerves. Their position in the abdominal wall is not constant. Often no more than two nerves are to be found. In that event the ilio-inguinal nerve has joined a portion of the genitocrural nerve, to form the external spermatic nerve, a name used collectively to designate those cerebrospinal nerves which innervate the spermatic cord, together with the cremaster muscle and the parietal portion of the tunica vaginalis propria. In

these operations a large nerve is found most often outward and upward in the incision, between the internal oblique and the aponeurosis of the external oblique. This nerve becomes subcutaneous a little above and to the outer side of the external abdominal ring, and sends branches to supply the integument over a great portion of this region. This nerve is the iliohypogastric. Lower down in the incision, often as far down as toward the furrow of Poupart's ligament, one or two additional nerves are to be found, also resting upon the internal oblique muscle—"the external spermatic nerve" (see above). This nerve emerges, together with the spermatic cord, through the external abdominal ring.

We inject No. 1 solution deep into the abdominal wall, outward and upward, corresponding to the intended skin incision. We thereafter inject the same solution between the aponeurosis of the external oblique and that of the internal oblique, with the intention of depositing the solution around the nerves just mentioned. Thereafter we make a subcutaneous injection in the extension of the skin incision and wait for half an hour.

One will always find complete loss of sensation of the skin, subcutaneous tissue, and aponeurosis. In case the cord be also completely insensible, there is no need of making an endoneural injection. Otherwise from 0.5 to 1 cc. of No. 2 should be injected into every nerve in sight. As soon as this has been done, one should immediately pick up the neck of the hernial sac. If it be not anesthetized, solution No. 1 is to be carefully injected in the subserosa above and laterally to it. The hernial sac is thereafter opened at the neck, and in case traction upon the parietal peritoneum should still cause pain, a liberal injection of No. 1 is made in the subserosa of the entire upper and lateral vicinity of the neck of the sac, under the guidance of a controlling finger in the abdominal cavity. Another place which may not always be found to have become anesthetized is the region around the pubic spine, which, aside from the above-named nerves, may also be innervated from the twelfth intercostal at the attachment of the rectus muscle. The sensitiveness in this situation should, therefore, now be ascertained, and, if necessary, an injection be made into the periosteum above and below the bone. The hernial sac is amputated at the neck, the peritoneum is drawn sufficiently forward and sutured under control of the eye. Small hernial sacs are extirpated; larger ones are left behind. It is of great advantage in these operations to lay bare the nerves. By so doing they are seen and respected and none of the larger branches are severed. It is of great importance not to destroy the external spermatic nerve, as the cremaster muscle would be paralyzed permanently.

Femoral Hernia.—After a local injection the hernial sac is laid bare. Then an injection is made around the neck of the sac, in order to anesthetize the adjacent portion of the parietal peritoneum. One can also do a regional anesthesia. In that case the skin is first incised above Poupart's ligament under local anesthesia; a small opening is made in the aponeurosis of the external oblique, and solution No. 2

injected into the ilio-inguinal and genitocrural nerves. Then follows the incision over the hernia, the laying bare of the hernial sac, and the injection around the neck of the sac.

Umbilical and Ventral Hernias.—The abdominal wall is rendered insensitive in the manner previously described for abdominal section. In case of umbilical hernia and ventral hernia in the median line, as soon as the hernial sac is opened, a careful injection of No. 1 is made into the subserosa of the abdominal wall around the hernia under control of a finger in the abdominal cavity. In other ventral hernias one need only anesthetize the subserosa above and at the sides of the hernia.

Suprapubic cystotomy is an operation which, in most cases, may be performed painlessly when it is a question of only the removal of a stone or pedunculated tumor, or for simple drainage of the bladder. Suppose that it is desired to make a transverse incision through the skin and a longitudinal one in the linea alba. A sufficient number of wheals having been produced, inject some of solution No. 1 or No. 2 into the loose connective tissue behind the linea alba, between the peritoneum and the posterior surface of the symphysis; then make a deep and a superficial injection in the linea alba, and so in the subcutaneous tissue; also in two layers, viz., close to the aponeurosis and close to the integument. In most cases suprapubic cystotomy appears to be a painless operation, even with an anesthesia of the abdominal wall only, as just described; but if the bladder be very irritable it may happen that every stitch in suturing, or the very grasping of the edges of the bladder incision with forceps, or touching the inside of the bladder with a finger will cause intense pain; which the patient does not refer to the operative field above the symphysis, but to the entire urethra, and, above all, to the meatus urinarius, to the entire perineum, and to the lower portion of the rectum (the pudic nerves).

If, in the patient's anamnesis, reference be made to a frequent and intense desire to urinate or to pains of the above nature, then the anesthetizing of the interior of the bladder and of the urethra, which I shall next describe, should be combined with that of the abdominal wall, or perhaps, better still, subarachnoid anesthesia may be employed.

In order to render the interior of the bladder insensitive, for example, to the crushing of a stone or an instillation of nitrate of silver, the bladder, according to Braun, should be filled with 150 cc. of a 0.1 per cent. cocain solution, to which have been added from 20 to 25 drops of adrenalin. Within from fifteen to thirty minutes the bladder has become anesthetized. In case of a painful, contracted bladder, it is best, at least one-half hour before the cocainization, to insert in the rectum a suppository of 0.01 or 0.015 gm. morphin, and 0.03 gm. extract of belladonna. The solution of 0.1 per cent. cocain (150 c.c.) with from 20 to 25 drops of adrenalin is to be kept at body heat in a glass irrigator or in a funnel, and should be allowed to run very slowly. As soon as a bladder contraction occurs, the solution is allowed to run

back and the tube is shut off. The tube is alternately opened and closed, while one patiently attempts to introduce into the bladder as much of the solution as possible, and to keep it there until the contractions cease, when the purpose—the anesthesia of the bladder—has been attained. This will far from always succeed. The operator, however, must not yield to the temptation of employing stronger solutions of cocain. He should bear in mind the numerous cases of poisoning, and even death, following injections of strong solutions of cocain into the urethra and the bladder. As I have just remarked, it may be perfectly justifiable to resort to subarachnoid anesthesia in order to render the bladder insensitive.

Penis and Urethra.—The penis receives its nervous supply from the pudic nerves. The integument, prepuce, and urethra are very sensitive. Whether the corpora cavernosa possess any sensibility in places where they have been dissected free from the adjacent connective tissue I cannot say. It is possible that their tunica albuginea has sensation, but their inner part—the cavernous tissue—surely has none.

Urethra.—In order to anesthetize the urethra, a Nélaton catheter is introduced into the bladder, and thereafter withdrawn to a point where the urine ceases to pass through it. Then from 5 to 7 cc. of solution No. 4 are injected very slowly, the catheter is removed, and the meatus kept closed for from ten to fifteen minutes. In cases of so-called impermeable strictures, a liberal amount of solution No. 4 with two drops of adrenalin to every cubic centimeter should be injected. When the meatus has been kept closed for fifteen minutes, it will be possible, as a rule, to pass a director through the stricture. In case a fine catheter can be passed, the posterior portion of the urethra is then anesthetized in the same manner. The dilatation of the stricture may now be accomplished almost painlessly. According to Reclus, even *internal urethrotomy* may be painlessly performed. This I have not tried, but an *external urethrotomy* may readily be done under local anesthesia. The urethra is first rendered insensitive in the manner already described. Then solution No. 2 is injected into the tissues between the rectum on one side, and the bulbous, the membranous, and the lowermost part of the prostatic portions of the urethra on the other. This is done under the control of a finger in the rectum. Then the same solution is injected beneath and at the sides of the corpus spongiosum, *i. e.*, in the bulbocavernosus muscle, to the extent of the intended incision. Thereafter an injection is made in the subcutaneous tissue. In suitable cases one may, naturally, just as well do a resection of the stricture, with suturing of the urethra, as a simple incision of the stricture.

Upon the *pendulous portion* all operations may be performed painlessly by doing a perineural injection of solution No. 2 or 3 around each dorsal nerve of the penis, at a point where the nerves emerge through the suspensory ligament, and a circular injection in the tunica albuginea of the corpora cavernosa, and also in the subcutaneous tissue at the root of the penis, to paralyze such sensory nerves which either are

derived from the scrotal nerves or which are given off from the dorsal nerves more proximally.

In operations for *phimosis* and *paraphimosis* a perineural injection, in the manner described, is made around each of the dorsal nerves, followed by an injection of No. 2 transversely in the tunica albuginea of the corpus spongiosum, to the extent of from 1.5 to 2 cm., and in the subcutaneous tissue and in the skin, one centimeter behind the frenum.

For *meatotomy*, either the above-mentioned transverse injection is made behind the frenum, or solution No. 3 is injected directly into the lower urethral wall.

Scrotum and Testes.—The scrotum is believed to be innervated partly from the lumbar plexus (the "external spermatic" nerve) and partly from the sacral plexus. It is, however, plain that either the statement as to the innervation of the scrotum from the lumbar plexus (Thane, in Quain's "Anatomy") is incorrect, or else its innervation varies. There are authentic cases (Kocher, Cushing) in which the scrotum has been innervated from the sacral plexus alone. Schwalbe, Rauber, Bardeleben, and I, from my own experience with local anesthesia of the scrotum, confirm this view about the sensibility of the testes. According to my investigations, those portions of the testicle and epididymis which are invested with serous membrane have no sensation; the parietal portion of the tunica vaginalis propria is endowed with sensation, and so also is the spermatic cord.

The entire scrotum, together with its contents, is easily anesthetized. First an injection of No. 2 or 3 is made into and closely around each spermatic cord. Then injections of No. 1 are made around the base of the scrotum, in the subcutaneous tissue and in the connective tissue on the symphysis and the muscles of the perineum, beginning the injections below the penis, then at the sides of the penis, proceeding thereafter upward to the inner side of the external abdominal ring, thence downward to the genitocrural fold, and then across the scrotum at the border of the perineum. One should also inject in the septum and in the connective tissue on to the hilus of the testes and on to the epididymis on both sides where they are not invested with serous membrane. The injection is to be continued around the base of the scrotum on the opposite side. In case one wishes to operate on one side of the scrotum only, this side alone should, naturally, be anesthetized. It is possible to do castration, extirpation of the entire or parts of the epididymis, to excise pieces of the testicle for examination, to do the various operations for hydrocele and varicocele absolutely painlessly and without any of the disturbing cremasteric reflexes.

Anus and Rectum.—The integument around the anus is very sensitive, but the rectal mucous membrane is void of sensation. The anal integument receives sensory nerve-branches from the pudic nerves, which also innervate the sphincter ani and both ischiorectal fossæ. There is no doubt that regional anesthesia may be successfully done in these fossæ, around the anal orifice, and in the depth of the perineum, in the entire penis, and in the medial portion of the integument of the

perineum and of the scrotum by injecting solution No. 4 around the pudic nerves where they enter each of the ischiorectal fossæ immediately above the sacrosciatic ligament. A few centimeters behind the anus the integument and subcutaneous tissue receive branches from the coccygeal nerves.

Local Anesthesia of the Anus.—With a fine needle four wheals are made in the skin—in front, behind, and one on either side of the anus. Through these wheals solution No. 1 is injected into the sphincter ani and in the connective tissue immediately above and around the sphincter muscle, in the subcutaneous tissue, and in the skin around the anus. With a finger in the rectum it is easy to control the direction and the position of the needle. The anesthesia may be extended forward or backward, according to indications. The injections may thus be made in the posterior raphé, and above this, around the coccyx, etc., and also in the anterior raphé and in either of the ischiorectal fossæ toward its outer side, in which case solution No. 2 should be used for both deep injections along the levator ani muscle and for superficial ones beneath the skin.

With these methods it will be possible to do a painless incision of the posterior raphé, to extend the incision backward and upward with extirpation of the coccyx, also painlessly or nearly so. Operations for fissure of anus, for hemorrhoids, for anal fistulas, if not too complicated, for abscesses of the ischiorectal fossæ, may be done painlessly. Also extirpations of the rectum (for ulcer, for cancer) may be done if, after the incision has been made between the rectum and the coccyx, the connective tissue be anesthetized higher up, behind, and at the sides of the rectum, under control of a finger in the rectum, an operation I have satisfactorily performed.

The Lower Extremities.—One should remember that here, as in the upper extremities, the bone-substance, the bone-marrow, and the cartilages have no sensation, but that the periosteum and the articular synovial membranes possess a sensitiveness to pain approaching in acuteness that of the integument.

Considering first operations of the *skin and the subcutaneous tissue*, it is apparent, from the course of the nerves and from their location where they become subcutaneous, that regional anesthesia may be quite extensively employed as follows:

(1) For the antero-external surface of the upper third of the thigh, by doing a perineural injection around the external cutaneous nerve, and, in addition, injecting No. 2 transversely below Poupart's ligament and above the greater trochanter, partly into the fascia lata, and partly just beneath the skin. (2) For the anterior surface of the lower two-thirds, by injecting in the same manner solution No. 2 transversely in the subcutaneous tissue at the junction of the upper and middle third of the thigh. (3) For the entire anterior surface of the leg and of the foot, excepting the toes, by making a perineural injection around the peroneal nerve, behind the head of the fibula, and around the long saphenous nerve, at the inner side of the knee, just where it becomes

subcutaneous, and connecting these points by injections transversely in the subcutaneous tissue. On the posterior surface, scarcely more than the subcutaneous tissue and the integument of the lower half of the leg are suited for a similar regional anesthesia by subcutaneous transverse injections at the middle of the calf. In other places one will have to do either a local injection at the site of the intended incision or else a circular injection around the entire operative field. It is plain that, even within those areas where a regional anesthesia is possible, a local injection or an injection encircling the operative field in selected cases may be much the simpler procedure.

Skin-grafting, according to the methods of Thiersch and Krause, all operations for *varicose veins* and ulcerations, etc., may be done under regional or local anesthesia, and after an infiltration of the periosteum, of the tibia or fibula, or if regional anesthesia has been done, one will be able also to chisel and curet these bones.

All operations upon the toes for ingrown nails, disarticulation of phalanges, etc., may be done painlessly by injecting No. 2 or 3 around the basal phalanx of a toe, so as to paralyze the four nerves. Disarticulation of an entire toe or amputation of a metatarsal bone may be done painlessly by injecting around the metatarsal bone, *i. e.*, first, behind its articulation with the tarsus, and, second, into both the adjoining interosseous spaces. I have just described perineural injections around the external cutaneous, the long saphenous, and the peroneal nerves. It is possible, although rather more difficult, to anesthetize also the posterior tibial nerve where it runs on the outer side of the posterior tibial vessels, between the flexor longus hallucis and the flexor longus digitorum, behind the ankle-joint. Using solution No. 3 or 4 the point of the needle is inserted on the inner (medial) side of the tendo Achillis. The anterior tibial nerve on the dorsum of the foot may be anesthetized by injecting either of the above-named solutions above the malleoli, between the anterior tibial and the extensor hallucis proprius muscles. In order to anesthetize the entire foot it is necessary—(1) to make these perineural injections with solution No. 3 or 4 around the posterior tibial and the anterior tibial nerves, and (2) to make an injection with No. 2 in the subcutaneous tissue around the leg, above the malleoli, into the muscular fascia, in order to cut off the conduction from the long saphenous nerve; (3) to inject beneath the fascia at the side of the tendo Achillis, because at times a part of the sural nerve may not become subcutaneous until at a point low down on the leg. When making plans for complicated anesthesias of this kind, one should not forget, in addition to illustrations on the course of the nerves, also to consult the illustrations of the cross-sections by Braun.

Simpler than the above-mentioned procedure for anesthesia of the *entire foot* is to anesthetize the *foot* and the *greater part of the leg* by a perineural injection around the saphenous nerve at the inner side of the knee, and by laying bare, under local anesthesia, the sciatic nerve at a distance above the popliteal space, between the biceps and the semitendinosus muscles, injecting into it solution No. 3.

Crile has performed *amputations of the leg* after endoneural injections into the crural nerve below Poupart's ligament, and into the sciatic nerve at the gluteal fold. In 1907 I did two such operations. Both the aged patients did very well. A less painful operation or a more satisfactory recovery is inconceivable, but these operations require time and must be painstakingly performed.

This anesthesia of the crural and the sciatic nerves (Crile) cannot be employed for resections of the knee-joint or for amputations of the thigh, because the entire group of adductor muscles, the integument on the inner side of the knee, and the periosteum of the diaphysis, and sometimes part of the posterior capsule of the knee, are supplied with sensory filaments from the obturator nerve.

As in amputations of the upper arm, so one can also perform amputations of the thigh and the leg after local injection of No. 1 from the depth (periosteum) to the surface (subcutaneous tissue). One should operate very carefully in the vicinity of all the larger nerves, which should be laid bare and injected with a few drops of No. 3 or 4 before they are divided. After local infiltration, one may painlessly perform arthrotomies in the ankle or knee, remove loose cartilages, suture the patella after fracture, suture the ligamentum patellæ and the aponeurosis above or at the side of the patella, etc.

I have done a few *disarticulations of the hip-joint* for advanced sarcoma of the femur in the following manner: Under local anesthesia and a very light general narcosis I first laid bare and temporarily clamped the common iliac artery with a Doyen intestinal clamp, covered with rubber tubing. Then I extirpated from above downward the connective tissue, together with the lymphatic glands along the iliac vessels. Next I injected cocain into the crural nerve and other branches of the lumbar plexus. Then followed ligation of the iliac vessels and disarticulation of the femur, and so the laying bare of the sciatic nerve and injection into it of cocain, etc. If the operation is done in this manner, the hemorrhage is slight and the shock *nil*.

The *major operations on the lower extremities*—resections, amputations, disarticulations, chiselings of the femur, etc.—are already now done, and will henceforth more often be done, under subarachnoid anesthesia. It is a much speedier procedure. But no surgeon ought to practise subarachnoid anesthesia who is not previously perfectly familiar with local and regional anesthesia. If he be not, he will of necessity make a wrong use of the subarachnoid method. He will also resort to its use in cases where he would have attained the purpose—painless operation—by a simple and an *entirely non-perilous* local anesthesia.

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[VENOUS ANESTHESIA.

FIG. 493.—*a–b*, THE PROXIMAL; *c–d*, THE DISTAL OR PERIPHERAL BANDAGE; *vb*, VENA BASILICA; *vc*, VENA CEPHALICA; *vm*, VENA MEDIA; +, THE PLACE WHERE THE INJECTION MAY BE MADE IN THE CEPHALIC AND AT A CORRESPONDING POINT IN THE BASILIC VEINS. SHADING SHOWS AREA OF SENSIBILITY BELOW THE PROXIMAL BANDAGE.

The Berlin Klin. Wochen., 1909, No. 11, publishes an important lecture by Bier, of Berlin, on what he named a year ago "Venous Anesthesia." He gives the technic fully. Briefly it is as follows: The solution used is one-half of 1 per cent. (0.5) of novocain in normal salt solution. The limb is made as nearly bloodless as possible by an Esmarch rubber bandage carried as high as necessary. Then a thinner rubber bandage is applied to keep the limb bloodless (Fig. 493, *a–b*). Below the lower limit of the operative field a second similar bandage is applied (Fig. 493, *c–d*). The anesthesia in the area between the two bandages he calls "direct," that beyond the lower bandage "indirect." A vein is then laid bare between the two bandages nearer to the proximal bandage than to the distal. Schleich's fluid is used. For the arm the basilic vein and for the leg the internal saphenous

are most frequently used. The vein is opened a little below the proximal band and the canula is inserted *not* in the central, but in the *peripheral direction.* From 20 to 60 ccm. of the novocain solution are then injected into the vein toward the hand or foot. "Direct" anesthesia follows between the two bandages in five or six minutes or less. "Indirect" anesthesia follows beyond the peripheral bandage in from six to ten or twenty minutes later, when the peripheral band can be removed and any operation be done painlessly anywhere below the proximal bandage, *e. g.*, amputation, resection, etc. There is usually some motor paralysis in the anesthetic area. Almost immediately after removal of the proximal bandage this motor paralysis disappears and sensibility is reëstablished in from two and one-half to seven minutes. He reports 134 operations by this method, of which 115 were entirely successful, 14 were "satisfactory," and 5 were unsatisfactory.—W. W. K.]

SUBARACHNOID (SPINAL) ANESTHESIA.

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By subarachnoid anesthesia, also often called *spinal* or *lumbar anesthesia*, is understood a method of rendering parts of the organism insensible by the injection of local anesthetics into the subarachnoid space of the spinal canal.

HISTORY.

In 1885 [1] J. Leonard Corning, the pioneer in local anesthesia, had already conceived the idea of producing a direct effect upon the spinal cord by the injection of cocain and other therapeutic agents in its vicinity. The cocain was to be injected between the spinous processes, hence to be carried to the cord by way of the veins which run to the venous plexuses in the spinal canal. He relates two experiments, one upon a dog and the other upon a patient with "spinal irritation."

Concerning these experiments, Corning expressed himself thus: "Whether the method will ever find an application as a substitute for etherization in genito-urinary or other branches of surgery, further experiments alone can show." In a later article (1888 [2]) Corning reports 4 cases of pain from disease of the spinal cord in which, with good results, he gave spinal injections of cocain. He does not here express himself on the surgical bearing of the method.

In the chapter on "The Irrigation of the Cauda Equina with Medical Fluids," in his monograph entitled "Pain in its Neuropathological, Diagnostic, Medicolegal, and Neurotherapeutic Relations," Philadelphia (1894), he advises that the cocain be injected directly into the lumbar sac by puncturing it between the first and second lumbar vertebræ. He reported two cases of disease of the spinal cord in which he made direct cocainization of the cauda equina. It is remarkable that these papers

of Corning evoked only slight attention. Although subarachnoid anesthesia had thus, in fact for the first time, been done by Corning, its significance was evidently not understood. It is another example of a great discovery the full significance of which was realized neither by the discoverer nor by his contemporaries. The lumbar puncture of Quincke (1891) was of great importance for further progress. Lumbar puncture having been established as a diagnostic and therapeutic method, the further step toward subarachnoid anesthesia was easier.

To Bier belongs undoubtedly the credit of having purposely produced anesthesia by the injection of local anesthetics directly onto the spinal cord, and also of having elaborated proper methods for its accomplishment.

Without being acquainted with the papers of Corning, Bier describes, in his "Versuche über Kocainisierung des Rückenmarkes" (Deutsch. Zeitschr. f. Chir., 1899), eight anesthesias which he had practised on himself, his assistant, and six patients. Lumbar puncture having first been made in the usual way, from 0.005 to 0.015 gm. cocain was injected, and in all the cases analgesia was produced in the legs, and after the larger doses up to the level of the navel. On the six patients major operations could be done painlessly or nearly so. But also the disadvantages of the method appeared promptly, as in most of the cases there occurred a severe and prolonged headache, which persisted for days. In his article Bier urges great care in the use of the method. In Germany the method was not very well received at first, but in France and America a number of enthusiasts eagerly investigated the method. Deaths were soon reported to have occurred as a result of the method. This caused some entirely to abandon it, while others endeavored to diminish the danger by improving the method, and at the German Surgical Congress in 1905, Bier called attention to improvements which had resulted in markedly lessening the dangers attending its use and the frequency of injurious sequelæ. These favorable results were obtained chiefly, first, by the employment of the less poisonous *stovain*, discovered by Fourneau in 1904; second, by the addition of one of the suprarenal preparations to the main local anesthetic, and, third, by an improved technic. Bier expressed the opinion that subarachnoid anesthesia, though not yet perfected, could, however, be recommended for clinical use.

Recently, besides stovain, *alypin*, *novocain*, and *tropacocain* have been introduced, and much has been done toward perfecting the technic.

ANATOMIC AND PHYSIOLOGIC REMARKS.

The spinal cord in the adult extends only to a level with the upper border of the second lumbar vertebra, when it becomes continuous with the filum terminale (see Fig. 494), which, as a bundle of connective tissue, extends to the termination of the dural sac at the second or third sacral vertebra. In a child the cord ends opposite the body of the third lumbar vertebra.

The arachnoid sac into which the injections are made is a more or less wide lymph-space, surrounding the brain and the spinal cord. Through the foramen of Magendie and the foramina lateralia the entire subarachnoid space and its contained cerebrospinal fluid are in communication with the ventricles of the brain. Poisons dissolved in the cerebrospinal fluid, therefore, through these foramina, may gain access to the inner lymph-spaces of the brain, and thus be brought in contact with vital nerve-centers, especially in the floor of the fourth ventricle. The arachnoid does not closely invest the spinal cord (see Figs. 494 and 495), a wide space being left between it and the pia. This space is, however, incompletely divided into an anterior and a posterior compartment by the ligamentum denticulatum (Fig. 495, *g*). In the posterior compartment are the sensory roots (Fig., 495, *f*), in the anterior, the motor roots (Fig. 495, *h*). This ligament forms practically a partition between the two compartments, for according to experiments made by Dönitz,[3] colored solutions (India ink) injected into the posterior compartment do not penetrate into the anterior. The posterior compartment is in the cervicodorsal portion of the spinal cord, subdivided in two halves by the posterior longitudinal ligament (Fig. 495, *c*). From the termination of the spinal cord at the second lumbar vertebra down to the end of the dural sac at the third sacral vertebra the subarachnoid sac is an undivided space (see Fig. 494) in which the nerve-roots run to their respective points of exit as a bunch of nerve-fibers, the cauda equina, which nearly fills the entire space. At the lower end of the spinal cord (conus medullaris), and a little below it, the nerve-roots are arranged in a right and a left bundle, with an intervening open space of from 2 to 5 mm. in width on a level with the second lumbar vertebra (see Fig. 497). Lower down the nerve-roots are more evenly spread out, filling the whole space, but leaving free room for the cerebrospinal fluid to filter through. In the cauda equina the motor roots are situated in the anterior portion, and the sensory roots in the posterior.

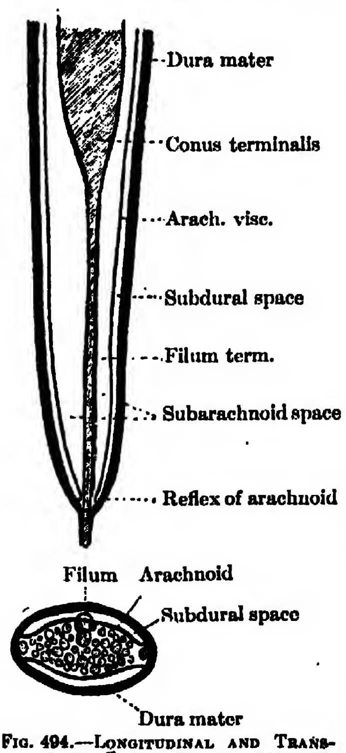

FIG. 494.—LONGITUDINAL AND TRANSVERSE SECTIONS, SHOWING THE ARACHNOID AT THE TERMINATION OF THE SPINAL CORD. PIA MATER RED. (After Poirier.)

The arachnoid is only separated by a very small interspace from the dura. Upon the outer surfaces of the dura, in the epidural space, especially at the sides, are rich venous plexuses and loose adipose tissue. It is also to be noted that the interspinous ligaments inter-

posed between the spinous processes may offer a decided resistance to the insertion of the needle in the midline. The distance from the skin to the subarachnoid space is in the lumbar region, generally from 4 to

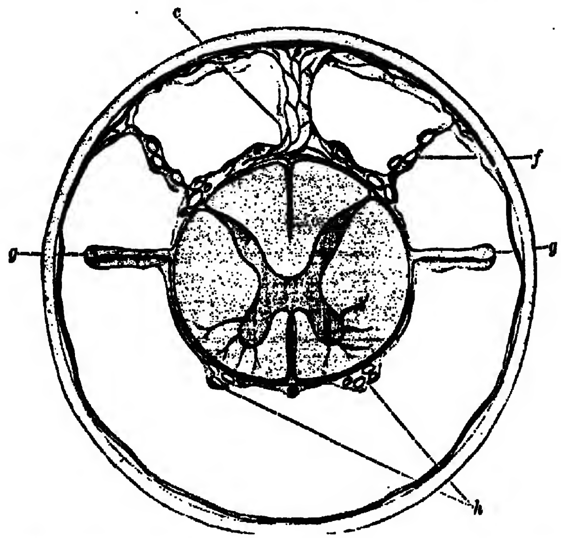

FIG. 495.—TRANSVERSE SECTION OF THE CORD IN THE UPPER DORSAL REGION. (After Key and Retzius.)

6 cm., but in men with well-developed muscles it may reach a depth of from 7 to 8 cm., and in fat persons even to 10 cm.[4]

As to the size of the spaces between the arches of the lumbar vertebræ, the third and fourth are, as a rule, larger than the first and the

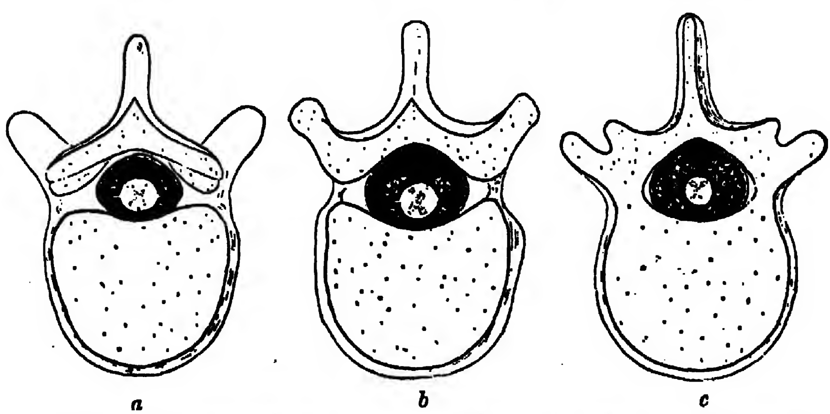

FIG. 496.—TRANSVERSE SECTIONS OF THE SPINAL CANAL. (According to Key and Retzius.) *a*, At the level of the ninth dorsal vertebra; *b*, at the level of the eleventh dorsal vertebra; *c*, at the level of the second lumbar vertebra.

second, while the fifth is narrower from above downward, but wider from side to side. The width of the interspaces is from 18 to 20 mm., and the height from 10 to 15 mm. In abnormal cases the spinous proc-

esses of the lumbar vertebræ may, however, cover each other in a tile-like manner, rendering the introduction of the needle impossible. Strong flexion of the lumbar spine increases the height of the interspace.

The cerebrospinal fluid is nearly as clear as water, very poor in albumin, with a specific gravity of 1.003–1.004.[6] The quantity, according to Key and Retzius,[7] is normally from 50 to 150 cc. The pressure in the lumbar region is, in the recumbent posture, equal to from 60 to 100 mm. of water.

Changes in posture affect to a high degree the position of the cerebrospinal fluid. Krönig and Gauss[6] believe that, in the sitting posture, the cerebrospinal fluid is practically at a level with the upper dorsal region of the cord, and in the recumbent posture, with the hips elevated, the fluid gravitates away from the lumbar region, so that not a drop can then be withdrawn by puncture. With a horizontal inclination of even 30 degrees the pressure of the cerebrospinal fluid in the lumbar region is at zero. If a coloring substance in solution be injected in the lumbar region, followed by a high Trendelenburg posture, the coloring-matter will appear at the base of the brain. The importance of this relative mobility of the cerebrospinal fluid is very plain if one considers that the local anesthetic used in the injection is diffused through the entire volume of the fluid, and is carried with it to the spinal cord and the brain. It is particularly important that the poison shall not reach the vital centers in a too strong concentration. In order to prevent such a diffuse poisoning of the entire cerebrospinal fluid, and to be able to tell precisely

Fig. 497.—Cauda Equina of an Adult. (½ life size.) (After Quincke.)

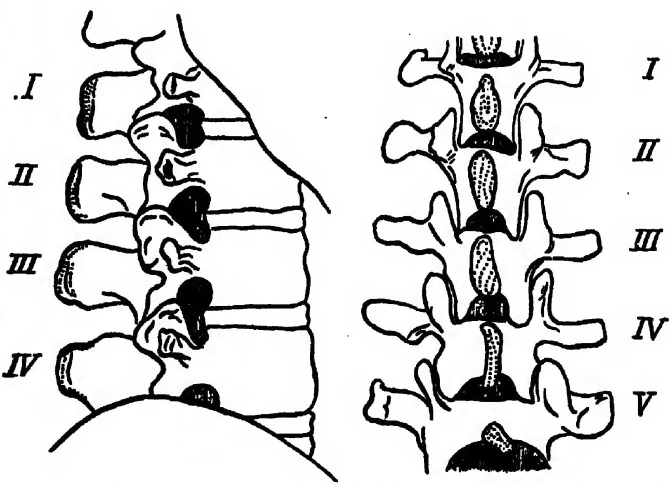

Fig. 498.—The Lumbar Column of the Vertebræ, Viewed from the Side and from Behind. (After Quincke.)

which point is being exposed to the effect of the anesthetic, Barker[5] employs for injection only those solutions which are heavier than the cerebrospinal fluid. If, moreover, by the addition of a suitable substance a different viscosity be given to the solution to be injected, this will with difficulty mix with the cerebrospinal fluid, and just as a heavy mass of oil easily changes place in a tube filled with a lighter fluid and always stays at the most dependent point, so, by changing the posture of the patient, one will always be able to calculate at which particular point the local anesthetic is being deposited, and, above all, by the very posture to prevent the poison from reaching the cervical region of the cord *en masse.*

ANESTHETICS.

Cocain was the anesthetic first used in subarachnoid anesthesia, but from the start it proved so dangerous, and the anesthesia was attended by so many serious complications, that the search for other agents was soon begun. Leaving out of consideration those agents which have been tried, but have been found to be unsatisfactory or too dangerous, we will now occupy ourselves only with those which are at present in use.

Tropacocain was discovered in 1891 by Giesel, and was first physiologically tested by Chadburne, of Boston. It is readily soluble in water, making a neutral, non-irritating solution. The solution will stand sterilization by boiling. It is one-third as poisonous as cocain,[28] and acts as a vasodilator. The anesthesia occurs sooner than with cocain, and lasts longer. It should *not* be used together with suprarenal preparations, as it counteracts their effect. In large doses, 0.12 gm., it may cause paralysis of the sphincters and stimulate intestinal peristalsis.

It is advised as the least dangerous agent by Bier, Braun, and many others. Complications arising during the anesthesia and the after-effects are said to be less troublesome than with any other anesthetic. Collapses and deaths are, however, mentioned. Because of its being less poisonous and comparatively free from complicating effects, it may be said that, at present, tropacocain is the anesthetic most frequently employed in subarachnoid anesthesia. The regular dose is from 0.03 to 0.05 and 0.06 gm., but may be increased to 0.12 gm.

Employed in a 5 per cent. solution, *stovain* was synthetically produced first by Fourneau (1904), and was used in subarachnoid anesthesia first by Chaput, and became for some time the anesthetic most in vogue. It is readily soluble in water, of a feebly acid reaction, and possesses noteworthy antiseptic properties. The solution may be sterilized by boiling. It is less poisonous than cocain, but the effect is more fleeting. It is somewhat irritating to the tissues, and in a 10 per cent. solution it may even produce gangrene. Contrary to cocain, it acts as a vasodilator, cerebral anemia being consequently less to be feared from its use in subarachnoid anesthesia. Stovain has, however, a more marked effect upon the motor nerves than has cocain. With stovain anesthesia the muscles in the anesthetic area become rapidly paralyzed. This is of advantage in operations upon the abdomen and the perineum, as the

wounds may be readily stretched. The strong effect of the stovain upon the motor nerves, however, may involve considerable danger, as in anesthesias extending higher up the respiratory muscles may easily become paralyzed, as well as injury done to the respiratory center in the medulla oblongata. It occasionally paralyzes the sphincter ani and contracts the intestines. This latter effect is of advantage in pelvic laparotomies in the Trendelenburg posture. Albuminuria after subarachnoid anesthesia with stovain is mentioned by Schwarz[7] as occurring in a large percentage of cases. Müller,[8] however, has only occasionally found a small, rapidly disappearing amount of albumin in the urine.

The regular dose is from 0.05 to 0.06, at most 0.07 gm. The solution from Billon, in Paris, comes in vials of 1 cc., containing 4 per cent. stovain, 0.11 per cent. NaCl, and 0.01 per cent. epirenin borate.

Novocain was produced synthetically in 1905 by Einhorn and Uhlfelder,[9] and was employed in subarachnoid anesthesia by Braun and others. It is readily soluble in water (1: 1), making a neutral solution. It may be heated to 120° C. without decomposition. It should not be heated for too long a time, together with the suprarenal preparations, because the latter will then decompose. It is considerably (seven times) less poisonous than cocain, affects very slightly the general condition of the patient, has no deleterious effect upon the heart's action, and in ordinary doses it does not lower the blood-pressure. Novocain is not irritating to the tissues, even if used in substance or in concentrated solution directly on wounds. Used alone, the anesthetic effect is quite fleeting, but together with suprarenal preparations the effect is prolonged and the intensity of the anesthesia becomes equal to that of cocain. Novocain possesses an affinity for the motor nerves in a considerably less degree than stovain. With a novocain subarachnoid anesthesia the legs are only slightly paretic, and the danger of respiratory paralysis is not so great. Pareses of the abducens have been reported after novocain. The complications are said to be less manifest than with stovain. Deaths are, however, reported. The regular dose is from 0.05 to 0.1 gm., but may be increased to 0.15 gm. It is employed in a 5 per cent. isotonic solution. It comes in ampullæ containing distilled water, 3 cc., novocain, 0.15 gm., and suprarenin borate, 0.000,325 gm., or in tablets each containing novocain 0.05 gm., suprarenin borate, 0.000,108 gm. Three tablets dissolved in 3 cc. of water make a 5 per cent. isotonic solution. Of this, 2 cc. are employed for operations upon the genitals and the perineum, from 2 to 2.5 cc. for operations on the legs up to the groin, and from 2.5 to 3 cc. for laparotomies.

In subarachnoid anesthesia, besides using the least dangerous anesthetic, it is also of considerable importance to employ the anesthetic in such a form as will do the least amount of injury to the tissues. In order not to lessen nor to increase the amount of liquid within the tissues the solution employed, in obedience to a general rule, should be isotonic with the tissues. The relation of the various agents in regard to this particular question is apparent from a table by Barker giving the specific gravity and the freezing-point of the respective substances:

	Specific Gravity.	Freezing-point.
Novocain (5 per cent. solution)	1.0090	0.555
Tropacocain (5 per cent. solution)	1.0106	0.545
Stovain (5 per cent. solution)	1.0064	0.585
Blood-serum	.....	0.56
Cerebrospinal fluid	1.007	

Guinard[10] and Kozlowsky[11] have solved the problem in the easiest manner by dissolving a weighed quantity of the anesthetic or of the tablets in the cerebrospinal fluid obtained when making the lumbar puncture. This method is very practical, but the objection may be raised that the possibility of chemical changes occurring in tablets which have been kept for a long time cannot be entirely excluded.

Tuffier, Bier, and a majority of surgeons employ the method of mixing in the syringe a certain quantity of the isotonic solution, for example, a 5 per cent. tropacocain solution with the cerebrospinal fluid in the syringe used for subarachnoid anesthesia. Barker[12] insists that the injected solution be heavier than the cerebrospinal fluid and of a somewhat different viscosity. Thus the injected solution will with difficulty mix with the cerebrospinal fluid, and by placing the patient in different postures, the anesthetic may be made to gravitate toward the most dependent point in the subarachnoid space, and thus become deposited at the place which is best suited for the intended operation. The solution, being heavier than the cerebrospinal fluid, can be prevented from reaching the cervical portion of the cord by always observing that the head and upper part of the back are higher than the lumbar and sacral portions. The solution employed by Barker contains 10 per cent. stovain, 5 per cent. grape-sugar, and 55 per cent. distilled water. The specific gravity of the mixture is 1.030, while that of the cerebrospinal fluid is 1.007. With this solution Barker has had especially good results. It should naturally not be mixed with the cerebrospinal fluid before injecting it. The alleged unreliability of the method is explained by Barker as due to the fact that the solutions employed are often lighter than the cerebrospinal fluid, which is especially the case with the stovain solution used by Bier, viz., stovain, 4 per cent., NaCl, 0.11 per cent., epirenin borate, 0.001 per cent., having a specific gravity of 0.0058.

Whether or not a *suprarenal preparation* should be added to the solution is a question which is being differently answered. We know that Bier, in 1905, referred to the addition of suprarenal preparations as a marked advance, inasmuch as they increased and prolonged the effect of the anesthetic. Recently, however, there is a reaction against the suprarenal preparations. That in *local* anesthesia the suprarenal preparations are of great consequence, inasmuch as they counteract the rapid absorption of the injected substance and thus give it a chance to act more powerfully upon the infiltrated area, is plain enough. In local anesthesia, then, the importance of the suprarenal preparations is being fully realized in case the anesthetic used does not oppose the effect of the suprarenal preparation (for example, tropacocain). In *subarachnoid* anesthesia the conditions are, however, quite different. Here

the various anesthetics are being deposited in a large lymph-space, and to "incarcerate" the anesthetizing agent within a certain area is out of the question. Our experience with suggillations in the skin, and even ecchymoses occurring after a local anesthesia, when adrenalin has been added, compels us to an attitude of doubt regarding the advisability of employing the suprarenal preparations in subarachnoid anesthesia. That corresponding changes in the pia mater may not be without consequence is clear as daylight, and may possibly explain the serious sequelæ which have occasionally been observed after subarachnoid anesthesia. I have also often observed that after local anesthesia, and especially when suprarenal preparations have been used, the patients have suffered severe pain in the operative field. When such objective and subjective changes are observed with a subcutaneous infiltration anesthesia, they are likely to occur in a still larger measure with subarachnoid anesthesia. Furthermore, the presence of suprarenal preparations complicates the sterilization, and the solutions do not keep for a long time after mixing, as the suprarenal preparations become decomposed. It is well known that solutions of cocain-adrenalin and of novocain-adrenalin, after being kept, and still more after being heated, assume a pink-brown color, suggesting decomposition. Such solutions should never be used, as they are especially prone to cause bad aftereffects. In using some of the anesthetics, the suprarenal preparations are contraindicated for the reason that their effect is destroyed by the anesthetic, *e. g.*, tropacocain, and to some extent also stovain.

Conclusions.—1. Among the anesthetics which so far have been employed, tropacocain is the least dangerous, and should be used in 5 per cent. solution with a dose of from 0.03 to 0.04 gm. for the perineum and the external genitals, 0.05 gm. for the legs up to Poupart's ligament, and 0.07 gm. for the abdomen. 2. The solution should be isotonic with the blood-serum, and heavier than the cerebrospinal fluid. 3 Suprarenal preparations should be avoided.

COURSE AND DURATION.

In some cases the anesthesia comes on at once and rises rapidly to its full extent, so that there is no time for observing the course. Generally, however, it proceeds more slowly. After about a minute there is a lessened sensibility to pain in the perineum, and the external genital organs and the inner side of the thighs. The patellar reflex disappears. Soon thereafter the ankle-clonus disappears, and the posterior surface of the thighs and legs, the soles of the feet, and the anterior surface of the legs and the thighs up to Poupart's ligament become insensitive to pain in the order named. Gradually the anesthesia extends up to the umbilical region, and at times perhaps still higher (horizontal posture). It is seen, therefore, that the anesthesia proceeds by segments, beginning with the fourth or fifth sacral segment, and extending up to the first lumbar segment. The anesthesia is dissociated, so that the sense of pain disappears first, and that of posture and touch later. It is con-

sequently wrong to test the occurrence of anesthesia by, for example, pricking the patient with a pin and asking if he feels it. The sense of touch is still intact, but the patient has no sensation of pain. In order to know whether anesthesia has occurred, one must compare the sensibility of a place outside of its reach with that of a place where the anesthesia is expected to be present. A more certain method is to test the disappearance of the reflexes, which surely denotes the approach of the anesthesia. Gradually the sense of touch and posture also is lost. Subjectively, the patient experiences a feeling of numbness in the legs. Motor disturbances may also set in, most often and most markedly with stovain anesthesia, but also with the use of cocain and tropacocain. The pareses begin in the muscles of the foot and extend rapidly upward, involving more markedly the extensors than the flexors.

The height to which the anesthesia extends depends upon a great variety of circumstances. With a larger dose the anesthesia extends higher up than with a smaller, but we should endeavor to employ the smallest efficient dose. It is plain that by dissolving a certain quantity of the anesthetic in a larger amount of the cerebrospinal fluid areas situated higher up may be reached.

We can also obtain higher anesthesias by elevation of the pelvis, as introduced by Klader. The cerebrospinal fluid then will run toward the head, carrying the injected anesthetic along with it. High anesthesias should not be produced with stovain, because of the danger of respiratory paralysis. If they are to be produced at all, the less dangerous tropacocain should be employed. Operations for goiter, thoracoplasty, and cancer of the breast have been performed in this manner. I wish to emphasize the need of great caution in elevation of the pelvis, as it may easily lead to respiratory paralysis and collapse—dangers to which Sandberg[13] has called particular attention.

It occasionally happens that the anesthesia is unilateral, an occurrence which, naturally, is extremely embarrassing in case, for example, the left side alone is anesthetized, when the operation is to be performed on the right. Dönitz[14] has offered a very plausible explanation for these unilateral anesthesias, viz., that the injection has not been made in the cisterna terminalis, but at the very beginning of the cauda equina, in either the right or the left bunch of nerve-fibers. There the anesthetic has been prevented from spreading about freely, it being only the adjacent roots of the cauda equina which have become affected by it.

It has been previously stated that in anesthesia with stovain and tropacocain the intestine becomes contracted, which might perhaps be of importance in operations for ileus. As far as I am aware no investigations or experiments have as yet been made directly to regulate intestinal peristalsis by agents injected into the subarachnoid space. After a subarachnoid anesthesia motion and sensation return much more slowly than they were lost, and, in the reverse order, so that the power of motion returns first, then the sense of posture and touch, and finally the sense of pain.

The duration of subarachnoid anesthesia is generally from three-quarters of an hour to one and one-half hours. Tropacocain anesthesias are, as a rule, of shorter duration than cocain and stovain anesthesias, while novocain anesthesia is said to last from two and one-half to three hours.

COMPLICATIONS AND SEQUELS.

Deaths.—During subarachnoid anesthesia it occasionally happens that the patients become nauseated and vomit, and are seized with a feeling of anguish and with headache. Occasionally, also, the patient turns pale and perspires profusely, while the pulse at times becomes small and weak. Cases of cessation of the respiration, and, in rare instances, death during anesthesia, also occur. Even after the anesthesia has passed away, complications of various kinds may at times appear.

A main group of sequels is spoken of under the name of *meningism*, a symptom-complex which has its origin in an aseptic irritation of the meninges. It consists of an intense headache, dizziness, nausea, vomiting, rigidity of the neck, tenderness to pressure over the cervical vertebræ, and pain in the small of the back.

The most frequent sequel consists of a headache, which, although light in most cases, may in some instances be severe. It is said to occur least often after tropacocain, while it is more common and more severe after novocain and stovain.

As remedies for the headache, morphin, antipyrin, quinin, an ice-bag to the head, etc., have been tried. Some have observed an amelioration from repeating the lumbar puncture; others have tried this without avail. Care should be taken that soda, carbolic acid, and other chemicals employed in the sterilization do not cling to the instruments, and thus become injected into the lumbar sac, where they are by no means indifferent. The instruments should be carefully rinsed in a physiologic saline solution, or, better still, no strong antiseptics should be used in the sterilization.

Hauber has often seen sleeplessness, at times lasting for seven nights, following subarachnoid anesthesia. Cases of pain at the site of the puncture (injury to the periosteum) and paresthesias in one or both legs (nerve lesions from the puncturing needle) have been reported by several authors.

Elevation of temperature, with or without chills, occurs, especially after *tropacocain*, while it is said not to occur after *novocain* and *stovain*. It is to be noted that the pulse in spite of the elevation of temperature, which at times goes above 39° C. (102.2° F.), is of normal frequency and strength, and that the patients do not become depressed from the fever. The fever is supposed to depend upon a direct irritation of the heat-center.

Should collapse occur, it is treated by injections of camphor, caffein, digalen, etc. Good effect has been noted from intravenous injections of NaCl with epirenin[16] (0.001 in 0.1 per cent. solution). Even *after*

subarachnoid anesthesia severe collapses may occur, especially if the patients do not maintain a horizontal position. Even cases of secondary hemorrhage are mentioned as occasionally following subarachnoid anesthesia. Kopfstein,[16] for example, reports such a case. A non-dangerous complication after tropacocain is mentioned by Urban,[17] who has had several cases of violent priapism, which is explained as caused by irritation of Goltz's erective center in the lumbar portion of the cord.

The most important sequels are, however, those pertaining to the motor functions. Most often it is the stovain which causes these effects, and to a less degree novocain and tropacocain. Cases of paralyses of the ocular muscles are occasionally mentioned. Most often one or both abducens, but also the trochlearis, have been affected. The paralysis is very similar to post-diphtheritic paralysis, inasmuch as it appears at a certain time (from four to eighteen days) after the anesthesia, and spontaneous recovery takes place in from twenty-one to thirty-six days. A toxic neuritis or a toxic change in the nerve nucleus offers, perhaps, the most plausible explanation. Oculomotor paralyses have occurred after lumbar puncture alone.

The pareses of the legs which normally occur with subarachnoid anesthesia may, occasionally, remain for several hours.

Especially after stovain anesthesia, there occurs, at times, a temporary paralysis of the sphincter ani, with involuntary defecation. Cases are also reported when patients are unable to void their urine, necessitating catheterization of the bladder for one or two days following. As is well known, however, this occurs occasionally also after general narcosis.

The most important paralyses which may occur during subarachnoid anesthesia are, without comparison, those of the respiration. They are caused by the anesthetic getting too high up, so as to paralyze the respiratory muscles, or they may be due to a direct action of the anesthetic upon the medulla oblongata. Dönitz has demonstrated, by animal experimentation, that stovain in the fourth ventricle will cause an arrest of the respiration, while the heart's action may continue even for thirty minutes. In order to avoid respiratory paralysis, especially with the use of stovain, which in this respect is the most dangerous, one should remember to take pains to prevent the anesthetic from traveling too high up, and repeatedly to test how high up the anesthetic has extended. In case it should be found to reach up to or above the clavicles, and out on the arms, then we should raise the patient, thus causing the poison to flow away from the cervical cord and the medulla oblongata. At times also a slow pulse, 40 or thereabouts, will indicate that the anesthetic has extended too far up, thus paralyzing the accelerating nerves of the heart. In case of respiratory paralysis, artificial respiration should be started immediately. In many cases this has a good chance of success, as the heart's action still continues.

It is difficult to get a definite idea of the frequency of deaths during

and after subarachnoid anesthesia. Hahn[18] gives 8 deaths in 708 subarachnoid anesthesias; Patterson[19], 20 in 7807; Reclus,[20] 6 in 2000; Zahradnicky,[21] 12 in 4679; Wainwright,[22] 14 in 16,300; and Strauss,[23] 46 in 22,717 cases.

In the above review the dark sides of the method have been related, showing the high mortality of subarachnoid anesthesia as compared with the mortality of general narcosis (chloroform, 1 in 3045; ether, 1 in 15,738, Zachrisson[24]). It may seem, therefore, as though subarachnoid anesthesia ought not to be considered. But it should be remembered that it is incorrect to compare these mortality figures, as a great number of patients operated upon under subarachnoid anesthesia are very low and unfit to be operated upon under general narcosis. If it were possible to make a full comparison, it might perhaps be found that large groups of operations, for example, prostatectomies, etc., under subarachnoid anesthesia, have a better prognosis, or by means of this method have become possible. Finally, we must remember that the above complications are in some cases due to technical errors and inexperience with the method, and that, with continued improvement in the method, its dangers will be lessened. For a comparison one should consider the first decade in the era of narcosis with the numerous deaths from chloroform and our present-day narcosis. Subarachnoid anesthesia has lived through its first decade, during which time a rich fund of experience has been gathered by which the method, in its future development, will be rendered less dangerous.

INDICATIONS AND CONTRA-INDICATIONS.

During the first experimental years of its existence subarachnoid anesthesia was employed in many places much too extensively. Now that we know more about subarachnoid anesthesia and its dangers, it will be necessary to give more definite indications for its use. As a general rule, it may be said that it should be used only in those cases in which general narcosis is, for one reason or another, inapplicable. Further, it should be used only in operations below the costal border. If the anesthesia extends higher, the danger of respiratory failure becomes too great. Operations on the genital organs, the perineum, and the rectum are especially suitable for subarachnoid anesthesia. Moreover, all operations about the leg are easily performed under subarachnoid anesthesia, and many authors consider also operations for hernia as suitable, but these operations are better performed with local anesthesia, according to the method of Cushing, as is customary in Lennander's clinic. Laparotomies in the lower part of the abdomen may be performed under subarachnoid anesthesia, but the peritoneum will seldom become entirely insensitive to pain, as it is innervated from segments which are situated high up. The majority of authors are agreed that subarachnoid anesthesia is unsuited to operations on children, as they are very susceptible to poisons and, as a rule, stand narcosis well. Moreover, it might psychically affect children badly to be oper-

ated upon while they retain their full consciousness. Aged patients, on the contrary, excluding the extremely old, bear this method very well.

In diseases of the spinal cord, or in such conditions where subarachnoid anesthesia will render the spinal cord a "*locus minoris resistentiæ,*" this method should be avoided. So, also, in cases of sepsis or pyemia (suppurative infections near the point of injection are naturally prohibitory to the method), the possibility of rendering the subarachnoid space accessible to metastases should be borne in mind. In the case of recent lues the method is contra-indicated. The method should not be employed in patients who are already in collapse, nor in patients who are in a state of nervous excitement.

TECHNIC.

For use in subarachnoid anesthesia, the "Record" syringe,[25] recommended by Bier, and a needle 9 cm. long, provided with a mandrel (Fig. 499), are the best. The syringe comes in several sizes, most commonly those holding 2 cc. are used, but even larger ones, up to 10 cc., are employed. The large-sized syringes are used by those who wish to mix the solutions or the tablets in the syringe (see section on Anesthetics, p. 1061) with a greater amount of the cerebrospinal fluid. For reasons already stated (p. 1088) I consider it safest to avoid this mixing, and also to avoid using the tablets, however convenient the use of the latter may be. It is better, like Barker, to have the solution unmixed with and heavier than the cerebrospinal fluid, as it in this way will be easier to determine its position within the subarachnoid space. A syringe holding 2 cc. consequently will well answer the purpose. Barker has also added a cannula, which fits on to the point of the syringe, and when carried through the needle reaches beyond its point. This cannula is intended to make sure that the solution is injected into the subarachnoid space. It might happen that the puncturing needle assumes a position as shown in Fig. 500. Only its very point has entered the subarachnoid space, and nothing prevents the cerebrospinal fluid from escaping. Believing that the needle is entirely within the subarachnoid space, the operator injects the anesthetic. Only a part of the solution, however, may enter the subarachnoid space, while the main part remains behind. By means of the cannula inserted into the puncturing needle one will always be able to reach beyond the point of the needle, and consequently be certain to be within the subarachnoid space (Fig. 501).

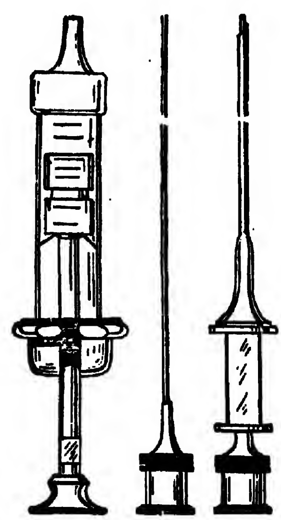

FIG. 499.—SYRINGE AND CANNULAS FOR SUBARACHNOID ANESTHESIA. (According to Barker.)

An indispensable requirement is that the armamentarium intended for subarachnoid anesthesia be kept separate, and be *used solely* for this purpose. In sterilizing the instruments one must carefully avoid boiling them in alkaline solutions, as alkalis may destroy the effects of the anesthetics. The instruments should, therefore, be sterilized by boiling in distilled water. Preceding the puncture, the integument of the lumbar region should be carefully disinfected in the customary manner. If sublimate or other strong antiseptics have been employed, they must be washed off with saline solution, to prevent their being carried by the puncturing needle into the spinal canal, where they might cause irritation. The disinfection is finished by washing with ether.

The puncture is most easily done with the patient sitting, the legs dangling, and back strongly flexed in the lumbar region. It is well

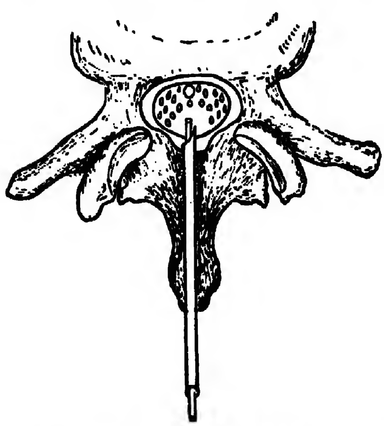

FIG. 590.—DEMONSTRATING THE USE OF THE INNER CANNULA, FOR INJECTION INTO THE SUBARACHNOID SPACE. (According to Barker.)

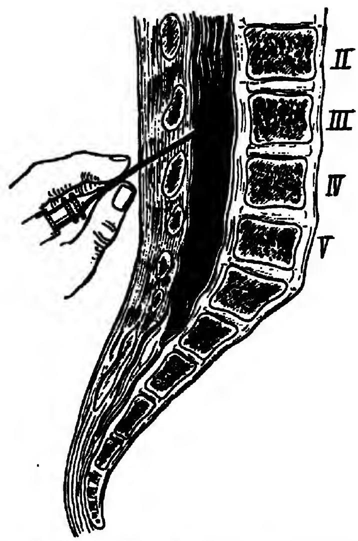

FIG. 501.—SIDE VIEW OF LUMBAR PUNCTURE BETWEEN THE THIRD AND FOURTH LUMBAR VERTEBRÆ.

to have a nurse stand in front of the patient to support him. The point for puncturing is either between the second and third or between the third and fourth lumbar vertebræ (Fig. 502). These points are easily located by palpation, starting from the spinous process of the fourth lumbar vertebra, which is found at a level with the highest points of the iliac crest. After a preceding ethyl chlorid anesthesia of the skin, the puncturing needle with the mandrel is introduced at the above-described point, straight in the midline. The needle is introduced firmly, taking care to keep straight in the midline, but giving it a slight upward direction. When the interspinal ligament has been pierced through, there is scarcely any further resistance to be felt. Many surgeons, however, prefer to insert the needle about one centimeter to the right or left of the midline (Fig. 501). The mandrel is removed, so that the escaping fluid may be immediately observed. By retaining the mandrel in place too long, one runs the risk of not know-

ing when the subarachnoid space has been entered, and one may even traverse the entire subarachnoid space and thrust the needle into its anterior wall. As has been said, the needle without mandrel is now pushed forward, and after having penetrated the dura and the arachnoid, which practically form one membrane, offering a characteristic slight resistance, the cisterna terminalis has been reached, and the cerebrospinal fluid escapes, dripping fast or in a continuous stream. If, in introducing the needle, it should happen to strike against a bone, it should be slightly withdrawn and its direction somewhat altered. In case only very little fluid should escape, the needle may be turned around or pushed a little forward, or slightly withdrawn,

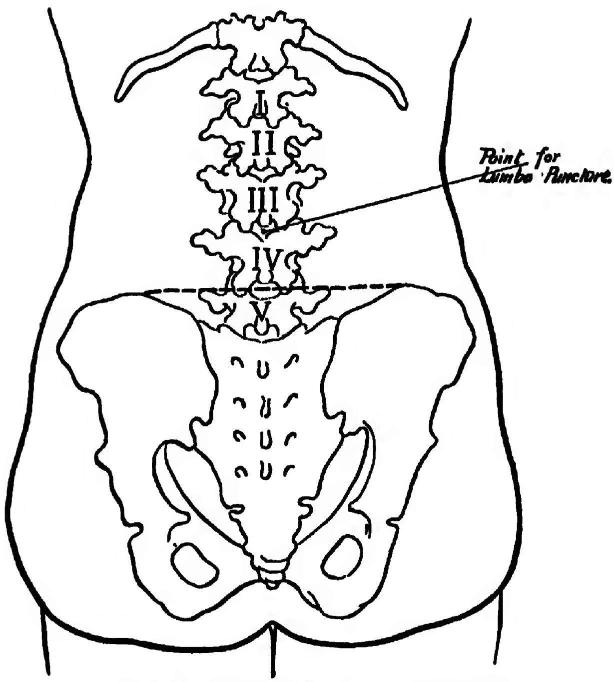

FIG. 502.—THE POINT FOR LUMBAR PUNCTURE.

until a freer flow is established. Should this not succeed, subarachnoid anesthesia had better be abandoned, for the reason that one might possibly have got in among the branches of the cauda equina. If, in spite of all this, the injection be completed, one runs the risk of getting a one-sided anesthesia. In case of hemorrhage, the puncture should be repeated at another point.

Provided, then, that all signs indicate that the cisterna terminalis has been successfully reached, from 7 to 10 cc. of the fluid is allowed to escape, when the anesthetic, held in readiness in the syringe with its cannula, is injected (in regard to dosage, see section on Anesthetics, p. 1088). If the cerebrospinal fluid is not clear, no injection should be made, but general narcosis should be resorted to. The cloudy fluid

should be most carefully examined bacteriologically and microscopically, of course. The needle, together with the cannula, is now quickly removed, and the opening covered with a piece of adhesive or collodion band. The patient is then slowly placed upon his back. A wedge-shaped pillow, about 10 cm. high, is placed under the pelvis. A pillow is also placed under the shoulders, in order to raise the cervical portion, and the head is supported and kept as much as possible bent forward on the chest. After waiting for the anesthesia to appear, the operation may be begun.

FIG. 503.—SHOWING FLEXED POSTURE OF PATIENT AND POINT FOR MAKING LUMBAR PUNCTURE, ONE CENTIMETER TO THE SIDE OF THE MEDIAN LINE, AND BETWEEN THE THIRD AND FOURTH LUMBAR SPINES.

Should subarachnoid anesthesia be done with the patient fasting or not? As in local anesthesia, so also in subarachnoid anesthesia, it has been proved best not to operate on an empty stomach, but, if possible, to allow the patient some food before the operation. Even during the course of the operation it may be well to stimulate the patient by permitting him to partake of wine, coffee, or other stimulants. If the patient has taken food, one is, as a rule, prevented, however, from continuing the operation under narcosis in case the anesthesia should not succeed.

In exceptional cases, when the patient is unable to assume the sitting posture, the puncture may be done while he lies on the side, with the knees sharply drawn up.[1] In order to diminish the psychic shock which the waking state during the operation will produce in some patients, Krönig, for example, has combined subarachnoid anesthesia with sleep-narcosis. Two hours before the operation the patients are given 0.0003 gm. scopolamin + 0.01 gm. morphin. One hour before the operation this dose is repeated, and if the patient, at the beginning of the operation, has not yet gone to sleep, another dose of 0.00015 gm. scopolamin is administered. It is perhaps too early to express an opinion as to the advisability of this method, but the heaping up of so many poisons is at first sight repugnant.

[1] In his latest contribution (Brit. Med. Jour., Feb. 1, 1908) Barker performs the puncture with the patient lying on his side, knees well drawn up, and a small pillow under the trochanter. Special attention is given to having the head and shoulders raised high. Only in operations upon the perineum is the injection made with the patient sitting.

In speaking of the technic, it will be well to dwell upon a phenomenon which, in many cases, is supposed to be due to some error in the method. At times it will happen that, even though the injection has been perfectly successful, still no anesthesia follows. To this class are naturally not to be referred those cases in which, on account of abnormal ossification or deformities of the spinal column, the injection has been impossible, but only those cases in which the injection has really been accomplished. A great variety of causes for these failures have been already touched upon. For example, it has been said that alkalis will destroy the effect of the anesthetic; that the injected solution, instead of entering the subarachnoid space, may possibly be deposited in the epidural space, or among the nerve-fibers at one side of the cauda equina, in which cases failures or one-sided anesthesias will be the result. Lazarus[26] has pointed out that, even in an eventual hemorrhage, the alkalinity of the blood would be sufficient to destroy the anesthesia. Moreover, too often repeated and violent sterilizations of the anesthetics should be thought of as possible causes, but, allowing for all these technical errors, there yet remains a group of cases in which the explanation of the failure must be ascribed to a certain insusceptibility to the anesthetizing agent. The frequency of these failures is very variously estimated by the different authors, and the majority of cases belong generally to the earlier series of spinal anesthesias, which goes to show that, with a more skilful technic, these failures are becoming more and more infrequent. Defranseschi,[27] for example, gives one such failure in 420 cases of tropacocain; Sonnenburg[28] and Holtzbach[29] none in 83 and 80 cases. The collected statistics from Moabit (Oelsner, *loc cit.*) give, however, no less than 63 cases in 875 cases of stovain and novocain subarachnoid anesthesia. In case of such an insufficient anesthesia, it will be necessary either to resort to narcosis, which has proved to be without danger or, if the maximum dose has not been given, to repeat the injection.

FINAL REMARKS.

I have sought to picture the present status of subarachnoid anesthesia. Certain difficulties in the method yet exist; but we have reason to believe that these difficulties will be overcome by continued work and additional experience, and I am of the opinion that the method, in a large number of cases, will be of great help, and that, for this reason, it will not be abandoned. Tropacocain is at the present time the anesthetic which is most frequently employed, and is the least dangerous. It seems to me that the right road for future work in this field has been pointed out by Barker,[30] who was the first to emphasize the importance of the weight of the injected solution, and other conditions within the subarachnoid space. Although a 5 per cent. solution of tropacocain is somewhat heavier than the cerebrospinal fluid, it might still be of advantage to increase its specific gravity by the addition of grape-sugar, thus substituting a tropacocain-grape-sugar solution for Barker's stovain-grape-sugar solution, in spite of the fact that stovain has, in the hands

of Barker, proved itself so free from danger. Subarachnoid anesthesia, however, cannot entirely take the place of narcosis because of its dangers, and should be used only in those cases in which narcosis is contra-indicated. An inconvenience for a great number of patients is also connected with the method, viz., it does not abolish consciousness, as Keen[31] (1897) says: "The ideal anesthetic will not be one which will abolish pain without abolishing consciousness. To have the patient aware of surgical emergencies which test even a veteran operator's skill and resources to the utmost would frequently invite death by the terror which it might occasion. The ideal anesthetic will abolish pain by the abolishment of consciousness, but without danger to life."

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CHAPTER LXXXII.

THE SURGERY OF THE INFECTIOUS DISEASES.

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Because of its importance and varied lesions, the first place may quite properly be assigned to typhoid fever.

THE SURGERY OF TYPHOID FEVER.

No disease can better illustrate the "Grenzgebiete der Medizin und Chirurgie." Hölscher found that 24 per cent. of 2000 fatal cases died of the fever, and 76 per cent. of the complications and sequels. These in great part are surgical. The profession is indebted to Keen for a monograph on "The Surgical Complications and Sequels of Typhoid Fever" * that may be called classic. It brought prominently forward, in convenient form, an immense amount of information and stimulated observation and inquiry among physicians and surgeons, and induced treatment that has led to a distinctly lessened rate of mortality.

The list of surgical complications is a long one, including intestinal perforation, inflammation of bones and joints, infection of the bile-passages, the formation of abscesses, intermuscular and glandular, etc. The wide distribution is more easily understood since the discovery of the bacillus of typhoid. Its presence in the blood in 85 or 90 per cent. of all cases makes more plain what would otherwise be inexplicable.

Perforation of the Bowel.—The most important and the most fatal complication is intestinal perforation. Its frequency has been estimated at from ½ of 1 to 11 per cent. Its relative frequency in mild and severe cases is not yet clearly determined, but it is quite probable that it is more common in the latter and in the ambulatory class.

Hölscher, in 2000 fatal typhoid cases, found 114 perforations, or 5.7 per cent. Osler found in 80 typhoid autopsies 20 perforations, or 25 per cent. In the Montreal General Hospital during the eight years just passed the percentage in the different years has varied from 2¾ to 9 per cent. In all there were 1405 cases of typhoid, with 70 perforations, or 4.98 per cent. Harte and Ashhurst [1] report a collection of 8881 cases, with 225 perforations, or 2.54 per cent., which would seem to represent a fair average.

That it is more frequent in the northern latitudes of both continents is the general impression. As contributory causes may be mentioned

* W. B. Saunders Co., Philadelphia, 1898.

intestinal parasites, unnecessary moving of the patient, vomiting, and extreme peristalsis (Zesas[2]).

The old rule to begin the treatment of typhoid by a good calomel purge at the outset may be really a scientific practice. It clears away a lot of deleterious decomposing matter, and leaves the long intestinal tube in a cleaner and healthier condition, and a less favorable field for those exciting causes which act mechanically by causing great distention, irregular peristalsis, and vomiting.

There do not seem to be any good grounds for attributing to the cold bath an increase in the frequency of this most unfortunate complication. True, symptoms of perforation have been observed during the administration of a bath. In a hospital where large numbers of cases receive the bath treatment it could hardly be otherwise. On the contrary, there is little doubt that perforations are at least quite as common in cases treated without as in those with baths.

Perforations occur with almost equal frequency during the third, fourth, and fifth weeks of typhoid. Osler observed one on the eighth day, and Briggs,[3] on the sixth day. It has been reported as occurring as late as the seventy-second, seventy-sixth, and one hundred and tenth day. Devic and Froment[4] discussed its occurrence late in the disease, and conclude that it has happened frequently during relapses in certain epidemics.

The perforations are generally in the lower part of the ileum, the terminal 3 feet (in 95.5 per cent. of cases within the first 18 inches), where there is the greatest abundance of lymphoid tissue. This is fortunate, in that it simplifies the diagnosis to some extent and directs the operator in finding and closing the opening. The exceptions, however, are of sufficient moment always to be borne in mind. It may be in the jejunum, in any part of the ileum, in the appendix, ascending, transverse, or descending colon, in the sigmoid, or in Meckel's diverticulum. Again, the perforation, although usually opposite the mesenteric attachment, where the lymphoid tissue is most abundant and the blood-supply least, may occur between the layers of the mesentery of the small or large bowel. In the latter case, the fact of its occurrence may only be definitely determined when a comparatively slowly developed abscess bulging into one or the other loin is evacuated. Within the abdomen such an abscess may be mistaken for a suppurating mesenteric gland.

Fortunately, in about 84 per cent. of the cases the perforation is single. The possibility of a second or third perforation being present must, however, be borne in mind. Spots likely soon to perforate may sometimes be unfolded and sutured over. Even more disappointing and disastrous are those second or third perforations occurring days after the closure of the first. In one of my own cases the second perforation occurred twenty-four days after the closure of the first. The third occurred four days later. The edges of the abdominal incision had parted when the stitches were removed after the second perforation, and the perforated coil of gut was exposed. Four days later a

fourth perforation occurred in the exposed and isolated intestine, with considerable hemorrhage.

The immediate results of perforation depend upon the full or empty state of the gut, the size and situation of the opening, the presence or absence of adhesions, the activity of the peristalsis, the bacteriology, the treatment, and the resisting power of the patient. There may follow an acute peritoneal sepsis, peritonitis with a yellow purulent exudate, or a fibrinopurulent peritonitis (Mikulicz). That an adhesive peritonitis may occur in typhoid perforation can no longer be questioned, although its rarity is well known. The adhesion may be to the abdominal wall, a neighboring coil of intestine, or a protecting fold of omentum.

Tavel and Lanz, as well as Benvenuti and Fedeli (Zesas[2]), have experimentally proved what had been suspected clinically, and shown at autopsies, that bacteria, and particularly colon bacilli, under favorable circumstances, can wander through the unperforated intestinal wall. Peritonitis may also be due to the transmigration of parasites through the diseased wall of the bowel (Ross[5]).

The changes in the lymphoid tissue consist chiefly in proliferation of the endothelial cells of the lymph- and blood-vessels. They show a marked tendency to gorge themselves with lymph-cells. This is aided by the mechanical ischemia produced by choking of the vascular channels and by the direct action of the typhoid toxins. The toxins would seem to be the agents producing the agglutination thrombosis of the erythrocytes in typhoid fever, and predispose to sloughing, either molecular or massive.

Although more common in adults, and at the age most susceptible to the typhoid poison, children are by no means exempt. In them typhoid is, as a rule, mild and extensive ulceration rare. Typhoid ulceration is said to be uniformly absent in the fetus. Griffith[6] reports 6 perforations in children under thirteen years of age, and Elsberg,[7] in a series of 289 cases, found 25 in children under fifteen years of age.

Symptoms.—The earliest, most important, most constant, and most suggestive symptom is pain. In the very great majority of cases its onset is sudden and severe, "le coup de poignard péritoneal." It is generally referred to the lower abdomen and often rather to the right of the median line. Exceptionally it is slight or even absent. This may be the case when some friendly adhesion seals the opening temporarily, when the patient is apathetic, or when the perforation is between the layers of the mesentery of the bowel. The location of the pain is dependent in part upon its situation, but sometimes is referred to unusual situations, as the end of the penis, the perineum or the epigastrium, for reasons not yet satisfactorily explained.

Tenderness, localized or general, is nearly always present.

Vomiting is by no means a constant symptom, but when present for the first time in association with pain and tenderness is significant. Increased resistance or rigidity is present, as a rule. Rounding up of the abdomen is nearly always apparent. The pulse generally loses quality, and the temperature alters, more commonly falls, more or less,

although an important rise is sometimes observed and is probably equally significant, notwithstanding Dieulafoy's dictum. Defecation and urination have succeeded the pain, within a few minutes, in a large number of our cases. The first stool consists of the feces present at the time in the rectum and sigmoid; frequently within an hour or two it is followed by another containing a tinge of blood. Suppression of stools is a less common occurrence. In addition to the above there is a changed expression, the patient has obviously altered for the worse, without, as a rule, passing at all into a condition of shock. Perforation is more frequent and more fatal in men than in women.

Diagnosis.—True it is that perforation is the most lethal complication of enteric fever, and equally true it is that early diagnosis is the most vital question in perforation, present or suspected. When the symptoms are all present, error is rare. The diagnosis is that of peritonitis. Peritonitis may be present without macroscopic perforation. This statement is confirmed by the Munich autopsies and by numerous operators, among whom may be mentioned Goodall,[8] Spencer, Hawkins, and many others. One might expect propagation peritonitis to be of a milder type, the pain less severe and more generalized, but Queirolo has shown that it may be attended by just as severe pain and just as acute an onset. No trustworthy guidance can be obtained from blood examination.

The great thing is a keen appreciation of the elusiveness of perforation, and constant watchfulness that the first and most indefinite evidence of its occurrence may not remain unnoticed. The diagnosis, often extremely difficult, sometimes impossible, can generally be made with comparative certainty. The difficulties are demonstrated by the occasional opening of an abdomen *intra vita* without finding any evidence of perforation, and post-mortem by finding an undiagnosed perforation with extensive peritoneal infection. Hence the opinion that, in doubtful cases, an exploratory incision is advisable and conservative. It is quite practicable to open the abdomen in a suspected case under local anesthesia. It is not always safe, however, to trust appearances at the point of incision. There may be no evidence of peritonitis, no intestinal contents or effusion visible, no free gas, and yet on going further and examining the first two or three feet of the ileum a perforation be found, nicely closed by adherent omentum.

The differential diagnosis of conditions simulating perforation is important. Hemorrhage, though not attended, as a rule, by much pain, is sometimes associated with perforation, as in a series of cases reported by Osler. In one instance, although no perforation was found, the operator probably saved a life by finding and arresting the bleeding.

Volvulus and intussusception may simulate perforation very closely and mislead the most astute.

Allyn[9] and Kiliani[10] report perforation of the gall-bladder in typhoid.

The usual rules of differentiation between these several conditions apply here as elsewhere. The possibility of their occurrence must be kept constantly in mind, but the difficulties are often overwhelming.

The differentiation between a perforation of the ileum within a few inches of the valve and a perforated appendix vermiformis, a right pyosalpinx, or a suppurating mesenteric gland can seldom be made with any degree of certainty.

Prognosis.—The prognosis in typhoid peritonitis is always grave. It is better, when not secondary to an actual perforation, when adhesions limit the spread of the infection, when recognized and treated early, and in women and children.

Treatment.—Von Leyden's suggestion in 1884, that the surgical was the only rational way of treating perforations of the stomach and intestines, came at a time when surgical technic justified its acceptance. The same year Mikulicz closed a typhoid perforation, in a male forty years of age, by suture. The operative method of treatment obtained favor in Germany, England, and America. In France it had no status until Dieulafoy presented a paper before the French Academy reciting the experiences of German and English-American surgeons. The results, gratifying to an extent, may yet be greatly improved by earlier diagnosis and improved technic.

In 1898 Keen collected 83 cases, of which 16, or 19.36 per cent., recovered. In 1904 Harte and Ashhurst[1] collected 362 cases, of which 94 or 25.97 per cent., recovered, and in the same year Zesas[2] reported 255 cases with 95 recoveries, or 37.25 per cent.

It seems fair to say that any series of cases collected from medical journals give a percentage of recoveries above what really obtains, for the simple reason that successes are more frequently reported than failures. A more correct estimate of the percentage of recoveries after operation is obtained by analyzing the figures of the hospitals, in which all the cases of perforation are included. If this is done, 25 per cent. of recoveries will be found to be a fair estimate of what has been attained up to the present. It should be observed that these figures represent the percentage of recoveries in cases operated upon. They do not represent the percentage of recovery from typhoid perforation. For instance, in the Montreal General Hospital during the past eight years 49 perforations were closed and 12 recovered, or 24.4 per cent. During that period, however, 70 perforations occurred in the hospital, so that while the percentage of recovery in cases operated upon was 24.4 per cent., only 17.1 per cent. of the total number of perforations recovered. Meakins[11] reports the results obtained in the Royal Victoria Hospital of Montreal during the past ten years. There were admitted 1230 cases of typhoid fever, and perforation occurred in 32, or 2.6 per cent. Twenty of these 32 were operated upon and 5 recovered, or 25 per cent., but only 15.6 per cent. of the total number of perforations recovered. In the remaining cases operation was not performed because of the hopeless condition of the patient, refusal on the part of the patient or friends to submit to the operation, or to non-recognition of the lesion. These figures strongly suggest the great necessity for constant vigilance, and the possibilities for greatly increasing our percentage of recoveries. In Elsberg's[7] series 64 per cent. of the children under fifteen years of

age recovered, but only 22.4 per cent. of the adults. In children the infiltration of the bowel-wall is less. If the mortality in typhoid from perforation is 30 per cent., as estimated by Osler, then we have reduced it by half in the cases operated on, but there is an enormous number still allowed to die for want of operation.

In considering operative details, the question of anesthesia assumes some importance. Under favorable circumstances the abdomen can be opened and the perforation closed under local anesthesia, the patient suffering comparatively little or even no pain. If there is much manipulation of the inflamed peritoneum, and if the patients are nervous and unwilling to bear pain—if they are children, frightened at the idea of an operation and at their surroundings, or if they are foreigners and no one is present who can converse with them intelligently, a general anesthetic is usually a necessity. The employment of local anesthesia should be the rule, reserving general anesthesia for the exceptional cases in which the former is inadequate. The patient may be washed and prepared before its administration, or, in exploratory cases, incision may be made under a local, and a general anesthetic be administered later, if required. The general experience is that typhoid patients do not suffer from a short administration of a general anesthetic, as in opening the abdomen and closing the perforation. In fact, very commonly their condition during the immediately succeeding twelve or fourteen hours is appreciably improved. Under a general anesthetic one certainly feels more at liberty to make a brief survey of the neighboring coils, perhaps closing in the base of neighboring ulcers or following the lead, as did Killiani,[10] when, after closing two perforations in the ileum, noticing a bright yellow color in the abdominal fluid, extended the incision and found two small perforations in the fundus of a gangrenous gall-bladder. Cholecystectomy was performed. This seems to be the only instance so far recorded of operation for apparently simultaneous perforation of the gall-bladder and ileum in typhoid. Allyn[9] reports a case in which a suspected perforation could not be found; the autopsy, however, revealed an opening 1 cc. in diameter in the gall-bladder, communicating with a small opening in the hepatic flexure of the colon. The simultaneous perforation of the gall-bladder and colon were apparently the result of contact infection.

Remembering the wide distribution of typhoid ulcers, one cannot but be on the alert to the possibility of more than one having perforated. Little need be said as to the time to operate. By common consent we may adopt Keen's rule: Operate at the earliest possible moment in the absence of shock. If shock is present and is severe, wait for a reasonable time, but not too long. The result obtained during the first twelve hours is better than during the second, and in the second than in the third. The situation of the pain and tenderness may suggest the point of incision. In the absence of special indication, it may be in the median line or a little to the right through the rectus. The perforation is, as a rule, easily and quickly closed by sutures. Exceptional conditions may demand exceptional resources—as, for example,

Da Costa's[12] case, where, between the perforation, which was situated a little over two feet from the valve and was closed by suture, and the valve itself, there were several ulcers on the point of perforating, one being at the extreme lower end of the ileum. To have inverted them would have destroyed the lumen of the bowel. The patient's condition was absolutely desperate, and resection was not to be thought of, particularly as the situation of the ulcers would have made it imperative to resect a portion of the colon with a portion of the ileum. He, therefore, performed an enterostomy on the proximal side by Bodine's method. Although secondary perforation occurred on the proximal segment of the gut ten days later, fortunately it was among the adhesions and not into the peritoneal cavity, and the patient ultimately recovered. Gibbon[13] is of the opinion that in such cases it is better to surround the perforated bowel with gauze and establish thorough drainage. Le Conte[14] coincides with Gibbon's[13] view that the safest plan is to wall off this area of intestine with gauze from the general peritoneal cavity. There is then less danger of a second perforation proving fatal, and the hazardous procedure of resection is avoided. Anderson,[15] impressed with the idea that death may be due to toxemia from the absorption of the contents of a paralyzed gut, tries partly to empty the bowel through the perforation before closing it.

The making of the toilet of the peritoneum is one upon which there is still great difference of opinion. Some carefully wash out the cavity with warm sterilized salt solution. A few wipe off the patches of adherent lymph, and it would appear that the majority drain freely. It may be said that some of the most satisfactory results have been obtained in cases where there was little or no washing, no wiping, and as little handling of the intestines as was possible. It is difficult to appreciate the unintentional traumatism caused to the delicate peritoneal surface by the most careful handling and douching of the peritoneal cavity. The recovery of the patient depends largely upon the normal or excessive functional activity of this great lymph-sac. To clean and sterilize is impossible without at the same time lessening the power of the peritoneum. Aside from the unavoidable traumatism, there is the great question of spreading the infection. The Fowler position must be used in these patients with care. No harm and much good may come from providing a way of escape for the seropurulent effusion and other matters by means of a cigarette drain or a tube carried to the bottom of the pelvis.

In extreme cases there would seem to be a great lack of reparative power, fortunately not observed within the abdomen, but seen in the almost complete absence of union between the edges of the incision. On removing the sutures on the fifteenth day or even later,—in one case on the twentieth day,—the edges fell apart. They looked pale and flabby and give no evidence whatever of repair.

A late sequel of typhoid ulceration is reported by Harrison Young. The lower twenty-two inches of the ileum were found in a state of chronic contraction two and one-half years after an attack of typhoid.

Sudden intestinal obstruction developed after a jolt on horseback. The patient died eighteen days later, with symptoms of a second attack of typhoid fever. The stricture was due to two bands in the submucous tissue, believed to be due to old typhoid ulcerations. There were old cicatrices of the mucous membrane, and four recent ulcers in the ileum, one of which had perforated. There was also a perforation in the cecum. The presence of post-typhoid narrowing of the lumen of the intestines is a demonstration of a mixed infection. Intestinal lesions due to the typhoid bacillus in pure culture recover perfectly and leave little trace of their previous existence. The ileum was enormously dilated above the constriction. The recent and fatal ulcerations were not thought to be typhoid in origin.

Stricture of the Esophagus after Typhoid Fever.—Esophageal stricture with complete closure, occurring in a male aged seventeen, after a severe typhoid followed by a tedious convalescence, is reported by Plummer[16]; other similar cases were collected by Keen.

Typhoid Appendicitis.—In their pathologic classification Kelly and Hurdon[17] note the following three types: 1. That in which the lymphoid tissue of the appendix participates in the typhoid lesions. 2. That in which a secondary infection with pyogenic organisms is ingrafted upon the typhoid infection. 3. Those in which a simple appendicitis develops, the appendix not being involved in the typhoid infection, but in which it is probable that the attack is precipitated by the congestion which accompanies the fever. That a gangrenous or a perforated appendicitis may occur during an attack of typhoid is obvious. Jopson[18] gives an interesting example. The difficulty in differentiating between an appendicitis and a typhoid perforation is fully recognized. The seriousness of a major operation during the course of typhoid is fully appreciated. The advisability of operating, therefore, is a subject of the keenest interest. The surgeon sails between Scylla and Charybdis. The humiliation involved in a needless operation is only exceeded by that felt on finding the operation undertaken too late.

Kelly, Murphy, and Deaver advise delay, emphasizing the high mortality of appendicitis in typhoid and advising operation only when there is pus or perforation.

The large percentage of recoveries in cases of typhoid perforation operated on after thirty-six hours is explained by the fact that a patient who survives the perforation so long has a mild infection, spreading slowly enough to permit a combative reaction on his part, or a limitation of the infection. Harte and Ashhurst[1] report 13 cases operated on within five days, with 4 recoveries; 2 cases within two weeks, with 1 recovery; 2 cases after two weeks, with 1 recovery.

Typhoid Perforation of the Gall-bladder.—Perforation of the gall-bladder in typhoid is a rare, but exceedingly fatal complication. In 1898 Keen was able to report 30 cases. In 1903 Erdman[19] reported 1 of his own and 3 others. In 1904 Willis[20] reported 1 case. In 1907 Kiliani[10] reported another case, unique in the coëxistence of 2 perfora-

tions of the ileum and a double perforation of the gall-bladder in the same patient. No others have been found in American, English, French, or German literature. Zesas,[2] in his very full paper reporting 250 cases of perforative peritonitis, makes no mention of gall-bladder perforations. Of the 36 cases, 4 recovered. Nine, including the 4 that recovered, were operated on. None recovered without operation.

The pathology of gall-bladder perforation is unlike that of intestinal perforation in that there are no aggregations of lymphoid tissue in the gall-bladder to undergo coagulation necrosis. It is, nevertheless, the result of infection. (*Vide infra.*) It is not yet clear whether in the cases of perforation the infection is of the mucosa, with subsequent ulceration, or of the gall-bladder wall with necrosis, or of the two conditions together. Nor can it be said whether the perforation is the result of infection with the typhoid bacillus in pure culture or in association with streptococci and staphylococci. It may occur independently of gall-stones. Of the 36 cases, gall-stones were present in 8 and absent in 17.

The fact that none of the cases not operated on survived, and that 4 of the 9 cases submitted to operation recovered, points clearly to the proper course to pursue. In Allyn's[0] case perforation was secondary to adhesion with the colon beneath.

Typhoid Infection of the Liver and Bile-passages.—That the liver becomes occasionally infected during enteric fever was noted by Louis in 1838 and by many subsequent writers. To bacteriology, however, we owe our present better understanding of the nature and path of the infection and its relation to hepatic abscess, cholelithiasis, and cholecystitis.

The rather astonishing discovery has now been made that a typhoid bacillus cholecystitis may be present in people in whom there is no evidence whatever of typhoid fever either past or present. Five such cases are reported by Pratt.[21]

Whether the bacilli pass to the liver by the bile-duct, the portal vein, or the hepatic artery is difficult to demonstrate; probably in all three ways. That they may live in the bile-passages for a long time is shown by Moynihan's[22] case, in which they were found in the bile in pure culture seven years after an attack of typhoid, and in Camac's case after twenty years. They are also found in gall-stones years after recovery from the fever. During typhoid a pure culture of the bacillus is more likely to be found there than elsewhere, and is no doubt often the cause of the not infrequent concurrent cholangitis and cholecystitis. In the opinion of many clinicians, the late exacerbations of fever and the relapses are, as suggested by Chiari, reinfections from the biliary tract. Doerr and others go so far as to suggest that typhoid patients are in some instances a menace to the community. I have just been consulted by a medical man for pain in the course of the colon, whose stools six years after an attack of typhoid contained typhoid bacilli in almost pure culture.

In the liver they lodge in the portal radicals. The liver is often

diffusely enlarged, and many abscesses are sometimes found, having a well-defined lining membrane. It is thought by Roger[23] that when the abscesses are single or few in number, the infection is through the hepatic artery. They are then of larger size and have no well-defined lining membrane. There may be present as coexisting conditions abscess in the parotid, mastoid, mesenteric glands, or a suppurating perichondritis of the larynx. When the infection has arrived through the ducts, the abscesses have no pyogenic membrane, the pus usually contains blood, is dark in color, and the surrounding hepatic tissue is markedly inflammatory. Jaundice is sometimes present. The pus is generally of a light color, except in pyosepticemic cases, when it is of a darker color. The prognosis is bad. They may live fifty or one hundred days and die of exhaustion or peritonitis. Some have recovered after passing blood in the stools. In the cases that have recovered the abscesses have probably followed a pylephlebitis. Treves operated in a case that recovered. Sheldon[24] could not find a case of hepatic abscess of arterial origin that got well.

Pain in the hepatic region, chills, enlargement of the liver, and tenderness are suggestive. The aspirator may be used as a diagnostic aid.

Single abscesses should be opened and drained. Surgical interference is contra-indicated in multiple abscesses, but drainage of the bile-passages through the gall-bladder may be of service.

Typhoid Pancreatitis.—Moynihan operated upon a boy thirteen years of age for recurring pains in the upper abdomen after a slow and unsatisfactory convalescence from typhoid. No gall-stones were found, but the head and part of the body of the pancreas were enlarged to double the normal size and very hard. The gall-bladder was drained for four weeks. After three weeks' drainage typhoid bacilli were still present. Urotropin was then administered, and they disappeared in a few days. Recovery was complete.

Typhoid Spleen.—**Splenic abscess** after typhoid has only been observed in about 20 cases. As to the path of infection, there is still much speculation. We can only say that when it is remembered that in 85 or 90 per cent. of typhoid patients the bacilli are found in the blood, it is perhaps a matter of wonder that we do not more frequently find these abscesses in the spleen and also in the brain, the lungs, liver, kidneys, pleura, pericardium, abdominal wall, and extremities. In addition to direct infection of the spleen itself there have been reported a few instances of subdiaphragmatic abscess on the left side, containing typhoid bacilli in pure culture, and thought to be secondary to splenic infection. Fortunately, the perisplenitis is a common accompaniment, uniting the spleen by adhesion to the parietes. Thirteen of the 20 cases so far reported died without operation. In 3 typhoid bacilli were found at post-mortem; 5 patients recovered after operation. In 2 of these typhoid bacilli were found; in 2 the pus was sterile and in 1 no bacteriologic examination was made (Esau[25]). In the sixth, the patient died after operation and streptococci were found in the pus.

In the seventh, the details of which have not been published, typhoid bacilli were found in the splenic abscess.

The diagnosis of splenic abscess is extremely difficult. It is sometimes a late complication, appearing after convalescence is established. Sweats and hectic fever may be present. A left-sided pleurisy may develop simultaneously and be of considerable diagnostic value. Splenic abscess must be differentiated from empyema. Importance should be given to the swelling, especially to the rapid development of the spleen, expansion of the left side of the abdomen, and the fact that when the patient turns upon the right side, a feeling of distress with difficulty in breathing is experienced. Pain in the left shoulder has been complained of.

The prognosis is good in early operation.

Treatment.—Evacuation of the pus is generally followed by quick recovery. The left pleura must be carefully avoided. Esau's[25] case developed sixty-two days after the beginning of the fever. The diagnosis was confirmed by puncture. The tumor continued to enlarge. Three days after aspiration the abscess was opened by an incision parallel with the lower border of the ribs. About 200 cc. of yellow pus with shreds of splenic tissue mixed with it were evacuated. Typhoid bacilli were not found. The patient made an excellent recovery.

Hemorrhage from the spleen in typhoid is rare. In 132 cases of rupture collected by Berger, 5 were suffering from typhoid. Kammerer[26] found a tear in the capsule in a case of typhoid from which the splenic tissue protruded like a mushroom. Another tear, followed by alarming hemorrhage, occurred during the manipulation, and he removed the spleen. The patient lived twelve hours. Berger states that "lesions exclusively of the capsule are without danger, because they do not cause hemorrhage."

Typhoid Osteitis and Periostitis.—The infection of the bones in typhoid is another evidence of the wide diffusion of the bacillus. The greater frequency with which some bones are invaded than others is striking. Of Keen's 216 cases, the tibia, femur, ulna, humerus, and ribs were the seat of the disease in 179, or over 82 per cent. In the forearm the ulna, which would be in contact with the bed, was involved 15 times and the radius only twice. In the leg the exposed tibia was affected 91 times and the fibula only 3 times.

Although a single focus is very common, yet multiple foci are by no means infrequent. In Fisk's[30] case there were 4 lesions; one over the crest of the right tibia, one over the ninth and tenth ribs, one over the supraspinous process of the right scapula, and one over the left hip. Many other examples are to be found in literature. There may be also multiple foci of disease in the same bone. In Brewer's[29] case there were 4 in one leg, both in the tibia and fibula, and 3 in the other leg. When 2 foci of disease are present in one bone, one may go on to resolution without the formation of pus or bone necrosis, and the other require incision and trephining of the bone, as in one of the Montreal General Hospital cases. Bone disease but rarely develops during the

course of the fever—more commonly during convalescence or the succeeding three to six weeks. In a number of cases, however, the disease has only appeared months or even two or three years after the fever.

It may be an osteitis, osteoperiostitis, or periostitis. In the reported cases there has been a vagueness in the discrimination between the different forms. This must of necessity be the case, because of the difficulty in differentiating clinically between periostitis and osteoperiostitis in the milder forms which do not suppurate. Pathologists assure me that there is distinct evidence found in the autopsy room of periostitis occurring without evidence of infection in the bone or the medullary canal, but in most cases coming to the operating-table there is evidence of the bone itself being involved as well as its covering. In many cases a painful tender node may appear and subside under the influence of rest and local treatment, or sometimes without any treatment. It may reappear again after a few weeks or months and again subside, and later on, perhaps, again reappear and go on to suppuration.

Etiology.—In rare instances the bone infection has extended into a joint and set up an arthritis.

The important pathologic factor in typhoid bone disease is the bacillus typhosus of Eberth, either alone or in association with some other microörganism, more commonly the staphylococcus or colon bacillus. It may be due to thrombosis, it, in turn, being due to large phagocytic endothelial cells which come, probably, from the spleen or other lymphatic tissue. Post-typhoid bone lesions are sometimes present without immediate association with typhoid bacilli. Mixed infection is very common, usually with staphylococci and colon bacilli from the intestines, where they are normally present. It is probable that the typhoid bacilli escape from the intestines through the bases of Peyer's patches, enter the blood-stream, and produce a typhoid septicemia of more or less virulence in 85 or 90 per cent. of all cases. We now know that in low states of the system other germs, the staphylococci and the colon bacilli, and probably the streptococci, may escape through the intestinal wall, in the normal parts of the gut, enter the blood-stream, and prove a source of mixed infection. This seems to be the most probable explanation of the determination of the exact locus in the bones and the presence of a pure typhoid or mixed infection in individual cases.

The late appearance of the bone lesions in a considerable number of the cases is in itself evidence that the typhoid and probably other germs as well may remain latent, but yet potent for a variable period, or until rendered active by some exciting cause. In other words, that there may be established a commensal relationship between the host and the pathogenic organisms. Schiller[27] found typhoid bacilli able to live and remain active on silk thread for one or two years. In Buschke's[31] case the typhoid bacilli had retained their vitality and pyogenic properties for over seven years. Clinically, it has been frequently noted that muscular exertion and traumatism have apparently been the exciting cause of the bone lesion at a time when the patient

seemed to be quite recovered and in good health. This has been noted in typhoid spine as well as in other skeletal bones.

Probably in the majority of cases the infection of the long bones is primarily in the medulla, spreading through the bone to the under surface of the periosteum. Small cavities form, sometimes filled with pus and sometimes with granular tissue. There may be a pocket in the medulla and another beneath the periosteum, the two connected by a narrow channel, forming Chantemesse's "bouton de chemise" or "shirt-stud abscess." Sequestrum formation occurs, but only rarely in comparison with sequestrum formation in ordinary osteomyelitis from pyogenic organisms. In Battle's[28] case perfect recovery without sequestrum occurred, although the periosteum had been separated all around from the shaft of the femur over its lower third. On the other hand, although, fortunately but rarely, a large sequestrum may form, as in Mears'[32] case, when a sequestrum was removed, consisting of the greater portion of the body or alveolar process of the upper jaw, with parts of the nasal, malar, and palatine processes, and the teeth as far forward as the canine. Keen suggests that blocking of a main trunk, or more likely a widespread vascular arrest in many smaller vessels, may be the cause of the extensive destruction both of the bone and the adjacent soft parts.

Horsley[33] collected 48 cases of osteomyelitis of the ribs and costal cartilages. Sequestra were found in 3 of them. They were small and easily removed, but they demonstrate that Paget's teaching that sequestrum formation did not occur in the ribs is not always true. In 20 of Horsley's cases more than one rib was involved. The fifth, sixth, seventh, and eighth were the ones more frequently affected. Forty were in women and seven in men, which is about the relative proportion in which the sexes suffer from typhoid bone disease in general. These patients were nearly all adults, the changes that occur with age, the vascularization, and the breaking of fibers in the intercellular substance being suggested as the reason. The frequency of rib involvement may in part be due to their superficial position and to their being constantly pulled up and down by the muscles.

The **symptoms** are those of a mild periostitis or osteomyelitis. Pain, tenderness, and swelling are present, with, as a rule, but little heat. Redness is a late symptom and generally indicates involvement of the overlying soft tissue. The constitutional symptoms are usually slight. If abscess forms in the soft tissue, fluctuation will be present.

The prognosis is good. Frequently the symptoms gradually subside without abscess formation and without operation. They may recur at the same or another point, weeks or months later, and while the patient is in apparent good health. This recurrence and subsidence may be repeated several times.

Treatment.—As soon as the nature of the lesion is recognized, the patient should rest, the part should, if possible, be elevated, and ice applied locally.

It is highly probable that the treatment by passive hyperemia

may be found exceedingly useful. According to the location of the disease, this may be best accomplished by the Stauungsbinde or the Saugapparat of Bier and Klapp.[34] This is hardly the place to discuss its *modus operandi,* but evidence of its efficiency in non-tuberculous as well as tuberculous disease of the bones, joints, and soft tissues is steadily accumulating. Superficial abscesses should be punctured and the Saugapparat applied.[34]

If the medulla of the long bones or ribs is involved, the bone should be trephined, the pus or granulation tissue removed with a sharp curet or chisel, and the cavity sterilized with pure carbolic acid, followed by alcohol or by a 1 per cent. solution of formalin. In favorable cases the cavity rapidly fills up. In others a sinus persists. In these latter cases it is altogether likely that the bacilli are widely diffused through the bone and had not all been removed. Here a resection of a larger portion of the bony walls will likely be successful. In the case of the ribs, costal cartilages, and sternum it is often necessary to resect a considerable portion. This must be done with care, as the underlying pleura is not likely to be much thickened and, therefore, is easily torn. The accident should not prove deleterious if a rigid technic is followed.

The length of time that a sinus may persist—months, in some cases years, exposed to all sorts of infection from dirty dressings or no dressings at all—and yet yield a pure culture of the typhoid bacillus is remarkable.

Typhoid Spine.—McCrae[36] has advanced our knowledge by demonstrating, in 2 cases, the deposit of new bone and its exact seat. "In one it filled the intervertebral space between the second and third lumbar vertebræ, apparently being deposited in the lateral ligament and forming bony union between the two vertebræ. In the second the process extended from the second to the fifth vertebræ, and appeared to involve both the lateral ligaments and part of the intervertebral disks."

It is more commonly observed in the lower dorsal and lumbar regions. These are the regions most dependent upon the muscles for support. They are the most movable parts, and the parts one would think most subject to strain, particularly toward the end of typhoid, when the muscular support is less than usual. Koenig[35] states that abscess and sequestrum formation may occur. Witzel has suggested that the back may be injured in the bathing of typhoid patients.

Fluss[37] emphasizes the necessity of avoiding overexertion or a fall after typhoid and other acute infectious diseases. In 6 of Lord's 26 cases mechanical strain preceded the onset; in 2 a fall; in 2 blacksmithing; in 1 stair-climbing, and in 1 twisting the spine while sawing. It is a rare complication. Fluss[37] collected 46 cases from literature and McCrae[36] adds 2. Pain is usually the principal symptom. It is generally referred to the lower dorsal or lumbar region, and may radiate around the body and down the legs. The pain in some cases is paroxysmal and occasionally of extreme severity, not easily influenced by morphin or other drugs. It is generally aggravated by any movement, and

the patient is in fear of being touched. Kuhn ascribes the spinal symptoms to inflammatory edema of the spinal cord, and Lord[36] to periostitis and pressure upon the nerves.

Fluss[37] found tenderness in 19 of his 46 cases, especially over the lower dorsal, lumbar, and sacral vertebræ. Paresthesia and anesthesia were present in 8 cases; the reflexes were altered in 11. Ankle-clonus was noted in 3 of Fluss's[37] cases.

McCrae's[38] skiagraph suggests that the spinal symptoms may be due to the pressure of new bone or a communicated inflammation. The altered reflexes, the wasting, and the disturbance of sensation indicate that the nerves are involved either by pressure or contiguity. Tenderness on pressure is a valuable sign. The presence of Kernig's sign has suggested the occurrence of pachymeningitis. Paratyphoid infections are of a similar nature. The resemblance to arthritis deformans is apparent. The fever present indicates organic change. Probably other tissues are involved, and it would seem fair to assume that the cartilages and the fibrous structures may take part in the inflammatory process. In other cases spondylitic arthritis may be present, although typhoid infection of any joint is rare.

In Neisser's[39] case an incision was made in the swelling of the right lumbar region, and a portion of muscle removed that showed marked degeneration with diminution of the nuclei, in part destruction of the sarcolemma, and vacuole formation. These changes were considered to be due to contiguity rather than to a secondary neuritis. The whole spine may be rendered rigid by muscular fixation. Scoliosis has been observed as present temporarily, and in some cases thought to be neurotic. Neurasthenia and hysteria, when present, are rather evidences of long-continued pain than of organic changes in the bones.

The resemblance to arthritis deformans has already been referred to. It is not unlikely that similar changes may occur after other infectious diseases, such as typhus, scarlet fever, influenza, endocarditis, measles, rheumatism, gonorrhea, tonsillitis, and pyemia. The subsequent course and development depend upon the bacteriology of the infection, particularly whether pyogenic or non-pyogenic.

Since Ponfick's first communication in 1893, evidence has been gradually accumulating that tends to establish his position as correct that nearly all the skeletal bones may be infected by the various acute infectious diseases. Witzel reports a series of cases in which an acute inflammation of the cervical joints followed diphtheria and scarlet fever, and Gibney, one of the cervical vertebræ being involved in typhoid.

When the infection is from the typhoid bacillus, recovery is the general rule. Only in some instances where mixed infection occurs is there abscess formation with destruction of tissue.

The pain, the dread of movement, the tenderness to pressure, the fixity, and occasional deformity render the diagnosis clear in most cases. If these patients are asked to pick up anything from the floor, they stoop as if suffering from Pott's disease, bending their knees and hips

and climbing up and down on their legs. Kyphosis, if present, would confirm the diagnosis. Deformity was present in 8 of Lord's[38] cases.

Treatment.—Rest in bed is important and may be necessary for a period of several months. In fact, rest in bed is the main reliance in the treatment. In severe cases, where the pain is not relieved by rest, immobilization is indicated. A leather corset may greatly increase the patient's comfort and contribute to recovery. Some have applied the cautery and antiphlogistic remedies. An ice-coil applied to the back is often soothing, and at the onset may be of value as an inhibitive remedy. In severe cases the treatment should be as active as for tuberculous spondylitis.

Schanz recommends placing the spine in a lordosis position as much as possible, as this relieves the pain. Newcome applied extension with an 8-pound weight for a month. Quincke also applied extension in one case, with improvement in six months. Franke emphasizes the necessity of extreme caution in the handling of all affections of the bones and joints after influenza and other infectious diseases. Irritation of the mildest form is likely to aggravate the condition. Mercurials are indicated if there is any suspicion of lues. Spondylitis typhosa would seem never to end in pus formation, even though accompanied by high fever and deformity (kyphosis). The entire arch of the fourth thoracic vertebra was found decayed. During convalescence massage is of service. These patients should be encouraged, as although the condition is tedious, lasting from two weeks to thirteen months, yet complete recovery is nearly always assured. It is probably safer to treat cases of persistent lumbago occurring after typhoid as typhoid spine.

Epidural Typhoid Abscess.—Intimately associated with the subject of typhoid spine is the following unusual as well as interesting case of abscess formation in the fatty and cellular tissue in the epidural space, reported by Raymond and Sicard.[40] A man, aged forty-eight, suffered from typhoid in January, 1905. In the following March, while still in the convalescent stage, he complained of severe pain in the right hypochondrium, right iliac fossa, and right leg. The iliac fossa seemed swollen and puffy. Motor and sensory paralysis gradually developed in the right leg and on the opposite side. In May, two and one-half months after the onset of the paralysis, there was almost complete paraplegia, accompanied by paroxysms of intense pain. Muscular atrophy was present, and the reaction of degeneration in the quadriceps and adductors of the right thigh. The area supplied by the crural nerve was sometimes hyperesthetic and sometimes hypo-esthetic. The sphincter, patellar, and Achilles tendon reflexes were absent. There was no clonus and no Babinski. The temperature varied between 98° and 101.5° F. Raymond and Guillain had published a case of ascending neuritis of the lumbar plexus after appendicitis, and the puffiness and the swelling in the right iliac fossa suggested the idea that this was a case of extension of infection from an appendicular focus—the metatyphoid of Dieulafoy. It was decided, however, to make an

exploratory lumbar puncture. To their great surprise, as soon as the needle penetrated the ligament between the third and fourth lumbar vertebræ and entered the epidural space, pus began to flow. On examination, it was found to contain typhoid bacilli. On the following day laminectomy was performed, the arches of the third and fourth lumbar vertebræ being removed. Half a spoonful of pus mixed with blood was obtained, and a drain left in position. The bones, so far as could be determined, were unaffected. By means of a Pravaz syringe a little cerebrospinal fluid was removed which was clear and devoid of cells. The symptoms gradually disappeared and the patient made a good recovery.

Typhoid Affections of the Joints.—The joints are not involved in typhoid with anything like the frequency with which the bones are affected. Keen found only 84 cases reported during a period of fifty years. Of the 84 cases, the lower extremities were affected in 70, the upper in only 17, 7 of the cases involving a joint in both. Surprising as it may be, spontaneous dislocation occurred in 43 of the 84 cases: 40 times in the hip, twice in the shoulder, and once in the knee. Almost all of the patients have been under twenty years of age. Rare instances of pyemic joints have been reported as occurring in typhoid. Much more common is the involvement of several joints, particularly the smaller ones, and generally regarded as rheumatic in character, whatever that may mean.

Interest centers largely in the monarticular form, the larger joints, particularly the hips, shoulders, elbows, and knees, being affected. There is not very uncommonly a moderate effusion, which, as a rule, disappears as unobtrusively as it came. In other instances the effusion increases in amount, the ligaments become stretched, and conditions favoring an easy dislocation obtain. The hip-joint has been dislocated oftener than any other. The strong unyielding Y-ligament holds firmly in front, and the head becomes displaced on the dorsum of the ileum. A poor girl was admitted to my own service, in the Montreal General Hospital some years ago, before the *x*-ray apparatus was available for diagnosis, with the right hip dislocated on the dorsum of the ileum, the left hip and both knees being at the same time firmly ankylosed. She had just recovered from a very severe form of enteric fever, and bore the scar of a huge bed-sore over the sacrum, an accompaniment of dislocation, by the way, not uncommon. In all cases in which suppuration occurs there is, in all probability, a mixed infection.

Achard et Bensaude[41] found the paracolon or paratyphoid bacillus in the pus removed from a suppurating sternoclavicular joint of an infant.

The possibility of serious joint trouble in typhoid patients, particularly in those under twenty, demands that more than cursory heed be given to all complaints of pain in or about the articulations. The inflammatory effusion can often be controlled by appropriate local treatment, and displacements prevented by securing and maintaining proper positions and preventing contractions that predispose to dislocation.

Typhoid Larynx.—According to Landgraf, laryngeal complications cause 11 per cent. of the mortality of enteric. Typhoid lesions of the larynx have special characteristics in regard to their seat, form, and course that are so typical that they form a separate class deservedly considered typhoidal.

In 1894 Schultz demonstrated the presence of typhoid bacilli in sections and cultures from swollen lymphoid nodules in the larynx. There may be a submucous laryngitis in which the deeper tissues are involved, or an ulcerative laryngitis or a perichondritis. According to Keen and Lüning, perichondritis followed by necrosis of the cartilages is the most common form of laryngeal disease in typhoid, the cricoid and next to it the arytenoid cartilage being most frequently involved. Ulcerations are common, but Keen thinks that perichondritis causes necrosis more frequently than ulceration. True typhoid ulcers are excavated with infiltrated areas around them, and are accompanied by important tissue changes. The non-typhoid ulcers resulting from other pyococci are superficial, only slightly undermined, without surrounding infiltration or damage to neighboring tissues. Typhoid ulcers show a marked predilection for the posterior laryngeal surfaces. They occupy the adenoid areas normally present in the larynx. The epiglottis is sometimes involved. The paralysis sometimes present may be due either to a peripheral neuritis or to pressure of enlarged lymphatic glands on the recurrent laryngeal nerve. Most cases are a distinct typhoid infection. Hoarseness and change in breathing direct attention to the larynx.

Treatment.—Steam, alone or medicated, gives relief in mild cases. If stenosis is present, the obstructive dyspnea may demand more radical treatment. Intubation has proved worse than useless. By common consent tracheotomy is the operation indicated. Of 26 cases, 10 recovered, and of these, 9 recovered after operation. Of 16 fatal cases, only 4 were operated upon. Of 60 cases recovering after typhoid perichondritis, 11 dispensed with the cannula in from seven months to six years; the others wore the cannula permanently. The treatment of post-typhoid cicatricial stenosis is unsatisfactory.

Sexual Organs.—Among the rarer complications of enteric fever are affections of the sexual organs in both the male and female.

Urethritis in the male has been observed in a few cases. It usually appeared during convalescence, and after continuing from one to three weeks, subsided spontaneously without treatment. The discharge was attended by painful micturition, which, in a case quoted by Keen, became bloody and was attended by symptoms of cystitis. Bacteriologically the discharge contained micrococci, especially the staphylococcus pyogenes aureus, but no typhoid bacilli and no gonococci.

More frequently orchitis and epididymitis have been observed. Wescott collected 32 cases. Orchitis was observed in only 4 of the series of 1500 cases analyzed by McCrae.[42] It usually appears late in the disease or during convalescence, and its onset is often accompanied by elevation of temperature and sometimes a chill. It is accompanied

by severe pain, the testicle being generally involved before the epididymis. The primary involvement of the testis is evidence in favor of a hematogenous infection.

In women ulcers sometimes appear on the posterior vaginal wall, destroy the septum, and produce a rectovaginal fistula. In Keen's case both a rectovaginal and vesicovaginal fistula were present. They resisted all attempts at closure. The urethra was finally removed, the vaginal outlet closed, and the urine and menstrual flow allowed to pass through the rectovaginal opening into the rectum. For at least twenty-two years afterward she was wonderfully well, able to earn her living as a nurse, and to mingle with people without being a source of annoyance.

Typhoid bacilli have been found in abscesses about the vagina, in ovarian abscesses, in dermoid cysts, and in peri-uterine hematoceles.

Gangrene may occur about the vagina or vulva in women, and has been followed by complete vaginal occlusion and retention of the menstrual blood. Gangrene about the anus or perineum may occur in either sex. The semiconscious state continuing for days, in a greatly reduced patient, together with the unavoidable soiling of the parts, certainly predispose to infection and gangrene unless the nursing is efficient.

A diagnosis of cystitis is made not infrequently. True cystitis in either sex is a rare complication, and when present, may be due to the colon bacillus, staphylococci, or typhoid bacilli. If the latter, the course is usually comparatively mild. When long persistent, the bladder mucous membrane may be thickened, and ulcers have been observed. Hemorrhages beneath the mucous membrane occur not infrequently.

Abscess of the prostate was observed at autopsy in one of the Johns Hopkins cases. The bacillus proteus was found in the pus.

GANGRENE FOLLOWING INFECTIOUS DISEASES.

Gangrene as a complication of typhoid resembles in nearly all particulars that associated with acute infection and the infectious diseases, including cholera, scarlet fever, measles, chicken-pox, malaria, diphtheria, influenza, pneumonia, erysipelas, rheumatism, etc. In more than one-half of the cases the lower extremities are involved. In females the genitals are frequently affected. The nose and other parts of the face, occasionally the ears and the anus, have suffered.

Pressure is undoubtedly the chief cause of the decubitus sores and gangrenous areas observed over the sacrum and about the ears and the heels. The female genitals and the scrotum are exposed to more or less moisture and decomposed secretions when personal hygiene is neglected.

Gangrene of the extremities is probably in nearly if not all cases due to a lessened blood-supply. The facility and readiness with which decubitus sores develop after complete transverse lesion of the spinal

cord demonstrate the importance of a normal nerve-supply, but so far no cases of gangrene from this cause seem to have been reported, even among the cases of typhoid spine. It is not by any means confined to those suffering from arteriosclerosis or heart disease.

Barraud[43] thinks that arteriosclerosis plays a minor part as an etiologic factor. Bacteriology has demonstrated the presence of the germs in the blood and walls of the blood-vessels. The thrombi would seem to be the direct result of injuries to the vessels by infection during convalescence after acute infectious diseases, and the thrombi to be autochthonous. Marked inflammatory changes may be present in all the coats. The prognosis is undoubtedly better in those in whom there was no preceding arteriosclerosis.

Arterial thrombosis greatly exceeds the venous in frequency. In Barraud's series there were 62 of arterial thrombosis with or without venous, and only 4 of purely venous thrombosis. Of the 62 cases, 11 had changes in the heart in the form of endocarditis or parietal thrombosis

Among predisposing causes may be mentioned lowered vitality of the tissues, a weak heart action, chronic nephritis, and diabetes. It is thought that many cases of spontaneous gangrene take origin in acute arthritis. The arteries most frequently involved are the popliteal, femoral, the aorta and its branches, and the iliacs. Embolic gangrene is more common in the late stages of pneumonia, constituting 40 per cent., and still more in acute rheumatism—80 per cent. In typhoid 7 per cent. are embolic, in the puerperium 11 per cent., and in the acute infections 10 per cent.

There is nothing distinctive in the symptomatology of the gangrene due to the infectious diseases.

Generally a line of demarcation forms, but sometimes the spreading is so continuous that if amputation is done at all, it must be before demarcation is distinct.

The mortality is exceedingly high. In Barraud's series, which included cases occurring in pre-antiseptic days, it was in typhoid 47 per cent., in the puerperium 44 per cent., in typhus 70 per cent., in rheumatism 80 per cent., in scarlet fever and pneumonia each 40 per cent., and in measles 33⅓ per cent. Among 45 recoveries were 36 amputations, 3 of them being spontaneous, and among 48 deaths were 16 amputations. While waiting, the extremity should be elevated and sepsis prevented as much as possible.

De Quervain recommends the local application of alcohol and formalin. If the sepsis increases and the gangrene spreads rapidly, amputation through sound tissue may offer the only chance of recovery.

SURGICAL DISEASES CAUSED BY THE PNEUMOCOCCUS.

Empyema.—(See Vol. III., p. 530.)

Abscess and Gangrene of the Lung.—The surgical conditions associated with pneumonia may be regarded rather as rare sequelæ

than as complications. Abscess and gangrene, though commonly consequent upon pneumonia, may depend upon other causes as well. Of 11 cases of gangrene in the Montreal General Hospital, 9 had a probable history of pneumonia; in the other 2 no satisfactory cause could be assigned. These cases are often late in coming to the surgeon—from the third to the tenth week—because of the desire to give methods other than surgical a fair trial, and because of the difficulty of localization. In a majority of our Montreal cases elastic tissue has been found in the sputum.

Treatment.—The treatment by aspiration and the injection of phenol or sublimate solutions has not proved successful (Mosler and Koch). These lesions cannot be approached satisfactorily without resection of one or two ribs, the second and third in front for lesions of the upper lobe, and the sixth, seventh, and eighth at the side and back for lesions of the middle and lower lobes.

The question of the presence or absence of adhesion between the visceral and parietal layers of the pleura is an important one to be decided after the subperiosteal resection of one or two ribs. If the two pleural surfaces are not adherent, incision of the parietal pleura may be followed by an in-rush of air and a certain amount of collapse of the lung, depending, of course, upon its adhesion to the chest-wall at other points, and to its physical condition and capacity to contract. In addition, there is the obvious danger of an infective pleuritis and empyema if the abscess of the lung is opened before fusion of two layers of the pleura has occurred. It is often difficult to decide whether these adhesions are present or not. The needle test is not often decisive.

In 87 per cent. of the cases (Quincke and Garrè) they are adherent. Sometimes evidence of adhesion is found in the thickening and inflammatory infiltration of the subperiosteal tissues. If in doubt, it is better to do the operation in two stages. After the resection of one or two ribs, with a round curved needle, suture the two layers together around the space exposed, or, as recommended by some, excite an adhesive inflammation by the local application of chlorid of zinc or turpentine or by firmly packing the wound with iodoform gauze. Two or three days later an incision may be safely made.

In urgent cases, should the lung recede and alarming dyspnea develop, if the lung can be caught by two or three pairs of forceps and brought out to the chest-wall, the breathing will become more tranquil (W. Müller). A row of sutures can then be passed around the opening and the abscess drained. Upon making an incision the in-rush of the air into the pleural cavity may be easily arrested by the finger and subsequent packing of the opening with gauze.

When gangrenous foci are near the surface of the lung, the superficial layers may be exceedingly friable, and deeply placed sutures may be required to hold the lung in position. However, a collapse of one lung is not often of serious import, and if infection be avoided, the air is gradually absorbed and the lung reëxpands. Of course, the other side should never be opened until the first is closed.

Superficial wounds of the lung seldom do harm and are quickly closed by blood-clots. On the other hand, deep wounds may injure important vessels and be followed by hemorrhage that can only be arrested by the application of ligatures. The opening of a large bronchus is sometimes followed by extravasation of air, but in this case the opening can often be closed by catgut sutures. It is hardly necessary to add that the opening in the chest-wall should not be allowed to close until the wound in the lung is healed. The opening in the gangrenous focus or the abscess-cavity may be made with a director and then enlarged with a pair of forceps, or may be made with a thermo-cautery. Unless a considerable layer of lung tissue overlies the cavity, there need be little fear of troublesome hemorrhage. After the cavity is emptied, the opening should be enlarged sufficiently to permit the introduction of the finger, that the size of the cavity may be determined and its relation to the diaphragm, the mediastinum, and, on the left side, to the pericardium; also the thickness of the wall, whether the opening made is at the upper or lower limit of the cavity, and whether the communication with the bronchus is at the top or at the bottom. In middle-lobe cases particularly a large bronchus may open into the upper part of the abscess-cavity, and the surgeon may find that his opening is also at the upper part. Drainage in this case is necessarily imperfect in the upright position, and, later on, a second and lower opening may be necessary before a cure is obtained.

Another cause of delay has been observed, particularly in cases of bronchiectasis, viz., persistence of a sinus due to epitheliation having extended along the drainage tract to the surface, which must be destroyed, or the opening be sutured before the sinus can be obliterated.

Garrè reports 400 cases of abscess, gangrene, and bronchiectasis treated surgically, with 300 recoveries, or a mortality of 25 per cent. The best results are obtained in abscess cases where the pus is not fetid, when a recovery of 87 per cent. was obtained. A larger mortality obtained in cases of gangrene, where 34 per cent. died, but even this is an exceedingly good result when compared with the 75 or 80 per cent. mortality under expectant treatment. The least favorable results seem to be obtained in bronchiectasis, which gives a mortality of 40 per cent.—the most favorable of these being those of saccular form, situated in the lower lobe. The walls and overlying pleura in these cases are sometimes exceedingly thick. Death in some cases is due to complications, such as a second focus of disease or to metastatic emboli in the brain. Subcutaneous emphysema is a familiar condition. Emphysema of the mediastinum is a possible accident, and when moderate in amount, may produce but few symptoms and pass unnoticed. In extreme cases there may be difficulty in breathing and swallowing. An effort may be made to control or remove the cause. The cardiac dulness may disappear and be replaced by a moist crackling synchronous with the apex-beat.

Pneumococcic Pericarditis.—Another rare but most important

complication of pneumonia in which the surgeon may be asked to cooperate is seropericarditis and pyopericarditis. Puncture of the pericardium, first proposed by Riolan in 1646, only became an accepted operation in 1840.

The best method of withdrawing fluid from the pericardium is still a matter of controversy. Schub used a trocar, and since that time paracentesis has been recognized, notwithstanding Trousseau's effort to substitute incision. At any rate, we have learned that the heart is a very tolerant organ, that the pericardium permits of great dilatation, and in pyopericarditis may be drained and irrigated with ease and safety. As much as 200, 300, 800, and 1000 grams of effusion have been found in the pericardium. In one case 1500 grams were removed at autopsy.

In the majority of cases the heart floats free in the fluid. It is not yet definitely determined whether, in the absence of adhesions, the heart lies nearer the anterior or posterior wall of the pericardium. Of the four methods of approaching the pericardium, but two require serious consideration. Trephining the sternum is seldom considered, and the same is true of approach from beneath the inferior border of the thoracic cage, starting from the xiphoid cartilage. Although puncture and incision must of necessity wound the pleura, yet, in the great majority of cases, if the diagnosis is correct, aspiration is a comparatively safe procedure, and if the effusion is serous, may be sufficient. If the effusion is purulent, incision and drainage are indicated. There is always the danger, however, of a mistaken diagnosis.

The difficulty in differentiating between pyopericarditis associated with single or double pneumonia and cardiac dilatation with adherent pericardium is recognized by all.

It is now proved that we need not fear to evacuate the fluid from the pericardium rapidly, and objections to incision based upon this argument no longer hold. In one case reported by Eiselsberg, after three punctures at intervals of a few days evacuating each time about 1 liter of pus, the fourth costal cartilage was resected and the pericardium incised. It still contained 2 liters of pus with large fibrinous clots.

Again, by incision, the pleura is safe-guarded against infection. The pericardium need not be opened until the pleura is safely fused with it. Incision with resection of one or more costal cartilages may be performed under local anesthesia. The advantages of incision are safety against wound of the heart, greater protection of the pleura from infection, a more complete emptying of the pericardium, and the removal of fibrinous masses so common in pneumococcic infections, together with the opportunity to establish efficient drainage and use frequent irrigation. (For the technic of the operation see p. 31.)

Peritonitis in Pneumonia.—The peritonitis occasionally associated with the onset and course of pneumonia may be a source of great perplexity to the physician, and his associate, the surgeon. It may be considered under three heads:

First, those symptoms sometimes present during the development of the pneumonia, and, in fact, constituting in themselves the chief objective and subjective signs in children and adults. The condition is often misleading, and on more than one occasion I have been summoned considerable distances to operate on such a case, diagnosed as appendicitis.

It would seem that in these cases there is a simultaneous infection of the lung and peritoneum, the latter nearly always subsiding as the disease develops in the former.

Whenever the onset of peritonitis is accompanied by rapid and catchy breathing, evidences of pneumonia should be carefully and repeatedly looked for. The physical signs of pneumonia may be found at the base, but not always. They are first observed in some cases in the mid-chest region, and without other evidence of the involvement of the diaphragmatic pleura.

Second, peritonitis may occur during the course of pneumonia about the sixth day, or two or three weeks later, more especially if the convalescence is slow. The onset is not as sudden as in peritonitis from perforation. Both children and adults may be affected, the former more frequently. The irritative matter enters the peritoneal cavity from the thorax by way of the lymph-vessels of the diaphragm or by the blood-stream.

In many cases the peritonitis remains or soon becomes localized, and ends in resolution and absorption of the inflammatory product. In these cases, however, adhesions, permanent in character, are not infrequently formed, and give rise to recurring colicky pain, and in some cases to symptoms of incomplete obstruction. In other cases localized abscess forms, with a tendency to develop anteriorly and open spontaneously near the navel.

Third, at the end of a severe pneumonia, in some instances neglected, there occasionally develops a profound sepsis, sometimes associated with pyopericardium, and an abdominal condition that is much in evidence and is most misleading. There may be extreme distention, complete constipation, and frequent regurgitation from the stomach of a dark-brown fluid, together with a small pulse, clammy surface, dry tongue, and anxious expression of countenance. At the autopsy the peritoneum is found perfectly smooth and unaltered, the distention and constipation being due to paralysis the result of sepsis.

Such cases are sometimes sent into the hospital as cases of obstruction. The differential diagnosis can generally be made by the absence of tenderness and rigidity and the presence of the associated conditions.

Pneumococcic Peritonitis.—Churton did not find one single case of peritonitis in 806 cases of pneumonia, and this notwithstanding the fact that pneumococci are present in the blood in nearly all cases of pneumonia. Netter was regularly able to demonstrate the pneumococcus in cover-slip preparations from the peritoneum in patients dying from pneumonia. This observation has been confirmed by Flexner and others.

Pneumonia, however, is by no means the only source of pneumococcic peritonitis. The infection may come from the throat, from the middle ear, and from intermuscular abscess not connected with bone. Not seldom it is a primary infection and not secondary to any other local disease.

The history of pneumococcic peritonitis began in 1885, when da Bozzolo[46] found numerous encapsulated cocci in the exudate from several serous cavities following nephritis. In the following year Cornil found pneumococci present in the peritoneal exudate after a case of pneumonia associated with double empyema and pyopericarditis. In 1903 von Bruns collected 57 cases of the disease in children and 15 in adults. In 1906 Annand and Bowen[48] reported 91 cases of pneumococcic peritonitis in children below the age of fifteen years. In 47 of these the peritoneal infection seemed to be primary and in 30 secondary to a pneumococcic infection of some other part of the body. In 14 it was impossible to say whether the infection of the peritoneum was primary or secondary.

Of the secondary cases, in 22, or 73 per cent., the primary lesion was in the lungs or pleura. Of the remaining 8, in 1 it was in the umbilicus; in 2, the throat; in 3, the middle ear, and in 2, intermuscular abscesses not connected with bone. In the primary cases the most likely source of infection seems to be the stomach and the intestinal canal.

Benzancon and Griffon found that pneumococci, varying in numbers and virulence, were present in the intestinal canal in nearly every case of pneumonia. Undoubtedly, in the majority of cases, they are destroyed by the gastric juice, as shown by Weichselbaum and Flexner. Cushing and Livingood think the bile has an inhibitory influence on them. When, as a result of disease, malignant or other, the gastric juice loses its acidity, pneumococci are no longer destroyed.

In 1891 Fränkel reported a case of fibrinous pneumococcic peritonitis together with carcinoma of the stomach and omentum. Pneumococci are usually found in greater numbers in the lower intestinal canal, and several cases of pneumococcic peritonitis arising from an inflamed appendix have been reported.

In 11 of Jensen's[47] 20 cases the infection apparently came from the intestinal canal. In 2 out of 3 patients with perforated gastric ulcer pneumococci were found.

Jensen[47] gave two young mice and two young rabbits 10 cm. of a highly virulent culture of pneumococci by the mouth. One rabbit had diarrhea, wasted, and died. A general fibrinopurulent peritonitis was found. The gut was injected, and although there was no ulceration, Peyer's patches were necrotic. Pneumococci were found in the wall of the gut and throughout the body. They have been found also in purulent echinococcus cysts, in the bile-passages, and in perinephritic abscesses.

The greater frequency of pneumococcic peritonitis in girls than in boys has suggested the entrance of the infection by the genital organs. Out of 58 cases reported by Jensen,[47] there were 7 boys and

51 girls. This does not prove, however, that the infection really enters through the genital organs, as generally at autopsy they are found perfectly sound. In adults the condition is somewhat different, 24 women and 16 men being affected. Pneumococci have seldom been found in pus-tubes, and would not seem to be normally present on the vulva or in the vagina or uterus. Cannon observed a pneumococcic peritonitis as a complication of cancer of the uterus and vagina. Another path is through the abdominal wall—as, for instance, during the operation for a radical cure for hernia.

Pneumococcic peritonitis has been observed even in a child one month old. It is three times as frequent in children as in adults, and under fifteen years of age it is seven times as frequent in girls as in boys. In adult life the two sexes are affected equally. It seems to be more common in spring and autumn.

The pus in pneumococcic infection is generally of a greenish-yellow color, frequently mixed with jelly-like masses, this last appearance being due to an intimate mixture of the purulent and fibrinous elements of the exudate. In cases in which post-mortem has been deferred for more than twenty-four hours the exudate may be evil smelling. A mixed infection may occur from the appendix or from gastric ulcer, but it is infrequent. When the process becomes localized in the pelvis or the hypogastrium, the limiting abscess-wall is unusually thick. When diffuse, it may cover every part of the peritoneum with a thick, fibrinous exudate. The strong tendency of the pneumococcus to form fibrin probably accounts for the frequency with which the inflammatory process becomes localized, hence the division of pneumococcic peritonitis into two classes—the circumscribed and the diffuse. Of 91 cases collected by Annand and Bowen,[48] 45 were encysted.

Jensen[47] states that in 25 cases of encapsulated peritonitis perforation of the umbilicus occurred in 7. Other cases have perforated through the vagina and one through the bladder. Perforation at other sites is rare. After spontaneous evacuation a cure may result, but more frequently drainage is required.

Primary diffuse pneumococcic peritonitis is characterized by acuteness of onset, severity of symptoms, rapid prostration of the patient, and in most cases early death. Of the 91 cases of Annand and Bowen,[48] 21 were of the primary diffuse form and 19 of the secondary diffuse form. Pericarditis, when present, is always associated with pneumonia, bronchopneumonia, or empyema.

The **diagnosis** of pneumococcic peritonitis may often be made from the clinical history, the peculiarities of which are the severe constitutional symptoms: apathy, weak heart, occasional dyspnea, dry tongue—the picture of some general infection. It has been most commonly mistaken for typhoid, but should be differentiated by the course of the temperature curve, the absence of rose-spots, the absence of enlarged spleen, and of the Widal reaction, and the appearance of peritoneal effusion, together with marked leukocytosis and polynuclear leukocytes. Herpes

labialis, which is sometimes present, is very uncommon in typhoid. In children there is sometimes a close resemblance to appendicitis.

The **prognosis** in the circumscribed form without complications and operated upon at the proper time is excellent.

Treatment of Pneumococcic Peritonitis.—The difficulties of determining the nature of the condition before a bacteriologic examination of the pus has been made are so great that treatment must be often undertaken before an exact diagnosis has been made.

In the encapsulated form incision and drainage are imperative and sufficient, and should be done promptly. The greenish, nonodorous, fibrinous pus will demonstrate pretty clearly the character of the infection.

In the diffuse form incision and drainage are equally imperative, and here again should be done without delay. If the pus is odorous, there is probably a mixed infection, perhaps with the colon bacilli, the source of which should be determined, if possible, and the treatment modified accordingly, as indicated by Munro in the chapter on the Surgery of the Peritoneum (Vol. III., p. 773).

Pneumococcic Arthritis.—Pneumococcic arthritis may be primary or secondary to pneumonia, pneumococcic otitis media, a general pneumococcus septicemia, or to operations. It is a very rare complication of pneumonia—1 in 800 cases (Herrick[50]), or 1 per cent., according to Rau. In 2 cases the joint affection preceded the commencement of the pneumonia by three and seven days respectively, and in 3 cases no pneumonia was ever present, the character of the joint trouble being demonstrated by finding pneumococci in the purulent joint effusion.

On the other hand, as shown by Smirnon, arthritis occurring during the course of pneumonia may be due to other than pneumococcic infection. In 5 out of 10 cases complicating pneumonia there were found such microörganisms as the typhoid bacilli, streptococci, and staphylococci. The nature of the infection can then be determined only by bacteriologic examination of the joint effusion and the blood. Here again a difficulty may arise from a bacteriologic point of view, as the fluid is sometimes found to be sterile, in which case, as suggested by Widal, the cocci may have died out. In other cases the joint effusion is secondary to toxins produced elsewhere in the body, or to a general pneumococcic septicemia, in which case the cerebrospinal fluid and blood contain pneumococci. The arthritis implies in most cases a bacteremia, although the exciting cause may be difficult to determine. Six of the 31 cases mentioned by Cave[54] were complicated by endocarditis, 5 by empyema, 6 by meningitis, 2 by pericarditis, and 1 by peritonitis.

Hermann[61] has shown experimentally that section of the sciatic nerve predisposes to the localization of staphylococci in the parts of a limb deprived of its innervation. The injection of a virulent culture of pneumococci into a joint is almost always followed by a suppurative arthritis. The subcutaneous injection after traumatism to the joints

or the injection of turpentine gives variable results, sometimes positive and sometimes negative. The intravenous injection after traumatism of the joint leads to arthritis more certainly than do subcutaneous injections. The incidence of arthritis would then, from clinical and experimental evidence, seem to be dependent upon some unusual vulnerability of the joint or to an excessive supply of pneumococci or toxins.

The larger joints are more frequently involved, and the upper extremity, particularly the shoulder-girdle. The knee, however is affected in a larger percentage of the cases than any other single joint.

The changes in the joints depend upon the virulence of the infection, its duration, and the resisting power of the individual. In moderate cases there are present only redness and thickening of the synovial membrane. In others the cartilage is eroded; the bones may be involved with sequestrum formation, as well as the tendon-sheaths and muscles near the joint. In a case reported by Witt[52] it was thought that there was a septic thrombosis in the arm, one of the rarest complications of pneumonia. Gabbi, Puritz, and Netter[53] have reported cases in which there occurred a peri-articular infection with abscess, the joint proper not being involved.

Cave,[54] who recorded the first case of pneumococcic arthritis in England, considered it essentially a disease of adult life. Among 31 cases he found only 2 children, five and eight years of age.

In 1906 Herzog[55] reported 25 cases and added 3 of his own, making 28 cases occurring in children under two years of age, generally confined to one large joint, and Nattan-Larrier,[56] from the clinic of Dieulafoy, placed on record apparently the only case of pneumococcic arthritis in a newborn infant following an operation for hare-lip.

In a few cases several joints have been affected. In 11 of Herzog's[55] 28 cases there was no evidence of antecedent pulmonary affections. In 8 similar cases between the ages of two and fourteen there were 5 without antecedent pulmonary affection, but in 55 cases in adults there were only 4 without pulmonary lesions. The most common primary focus in children is the middle ear. In the fatal cases death is nearly always due to such complications as endocarditis, empyema, meningitis, pericarditis, peritonitis, and septicemia.

The clinical features are somewhat characteristic. The temperature varies from 99° to 104° F. Even when there is considerable fever the child's face is generally pale. Locally, there is well-marked swelling and edema, with increased heat, but, as a rule, no redness, and this is regarded as an important diagnostic feature between this and other forms of arthritis. In rare cases an abnormal mobility has been observed. The child may retain a fair appetite and sleep well.

Prognosis.—Of the 52 cases reported by Herrick,[50] 35 died, a mortality of 65 per cent., a small part of it only being due to disease of the joints. Of Herzog's[55] 28 cases, 14 recovered and 11 died; in 3 there was no report. When there is no great destruction of tissue within and about the joint, functional recovery is generally good, with nearly a normal range of motion.

The treatment is obviously surgical. Salicylates are useless. Rest, fixation, and ice may be applied at first and may be followed by recovery.

When effusion into the joint occurs, it should be aspirated and examined bacteriologically. If several joints are affected, the fluid from each should be examined, as its character may vary in the different joints. In the case of a child reported by Dudgeon and Branson, the fluid from the elbow was a pale yellow sero-pus, from the knee a clear serum, and from an abscess in the neck a thick yellow pus.

Sufficient has been said to confirm the statement of Thacker that the pneumococcus should be "ranked with the virulent staphylococcus and streptococcus as a pyogenic germ."

By the facility with which it enters and circulates in the blood-stream it is enabled to reach all parts of the body, and we find it present in pure culture, and as the sole infective agent not only in the lungs, pleura, pericardium, and endocardium, but also in the bladder, kidneys, peritoneum, joints, bones, bile-passages, upper air-passages, middle ear, veins, and in numerous superficial and muscular abscesses. Osler states that the pneumococcus is the most common cause of sporadic meningitis.

Pneumococci are widespread in the soil and dust, and Germano has demonstrated that, planted in neutral media, they may be found living after six months, and that they may retain their virulence even better when dry than when moist.

THE SURGERY OF THE PUERPERIUM.

Very considerable surgical interest attaches to the periods of gestation and the puerperium. During gestation it is sometimes necessary to decide as to whether some operation may be undertaken, varying in severity from the extraction of a tooth to the trephining of a mastoid, the removal of an inflamed vermiform appendix or a malignant neoplasm. In some cases operation would seem to be imperative—when, for instance, there is pus in the middle ear, in the brain, in the lungs, pericardium, gall-bladder, liver, or kidneys. In other cases it is a matter of opinion or expediency, as in the presence of malignant disease in the breast or sarcomatous growth in one of the bones. In a general way it may be said that the earlier in the period of gestation, the safer is the operation, and the less likelihood of gestation being interrupted.

The essence of the question, however, as indicated by Fellner,[60] would seem to depend largely upon the physical condition of the mother. If there is renal insufficiency, the slightest operation is likely to be followed by abortion. On the other hand, if the physical condition of the mother is satisfactory, operations may be carried out on the external genitals or the cervix without interruption of pregnancy. Again, the question of abortion depends, no doubt, somewhat upon the severity and mutilating character of the operation. Prolonged anesthesia undoubtedly contributes to the occurrence of miscarriage.

The percentage of cases in which pregnancy is interrupted in appendicitis is not greater when operated on than when not operated on, and

occurs in from 35 to 44 per cent. of the cases. When labor follows soon after the removal of the appendix, the prognosis is not so good. It is absolutely bad when the abscess is opened and drained without removal of the appendix. It is sometimes wise to empty the uterus before undertaking major operations.

Pasteur and Doléris, in 1880, demonstrated that streptococci were the common cause of puerperal sepsis. Many observers have added their quota, and now we know that staphylococci, pneumococci, gonococci, colon bacilli, and the bacillus capsulatus aërogenes may also be the agents of infection. They spread by the lymph- and blood-vessels, rather than by continuity of surface, through the Fallopian tubes. The veins and lymphatics of the broad ligaments are especially involved.

The operative treatment of puerperal infection has assumed a conspicuous place. The existence of infected Fallopian tubes has long been recognized. The surgical treatment of parametric abscesses and inflammatory exudates is established upon a practical basis. In puerperal peritonitis, incision and drainage are indicated without irrigation.

Trendelenburg's suggestion to resect or ligate the veins of the broad ligament is of doubtful value. Under favorable circumstances and when isolated suppurating mesenteric glands may be opened and wiped out. Hysterectomy should only be considered when the uterine walls are the seat of suppurating foci. Drainage should be instituted as early as possible. Drainage through the vagina, unless combined with laparotomy, does not offer an opportunity of searching for other foci.

The use of Marmorek's serum, introduced in 1895, has been given a most extensive trial. The exhaustive report of a committee of the American Gynecologic Society in 1899 that, while harmless, it was of doubtful therapeutic value, has, in the main, been confirmed by many independent observers. Bumm and Rau, however, find it occasionally of value. It does not act directly upon the streptococci, but stimulates poikilocytosis. The induction of leukocytosis by the intraperitoneal injection of nucleic acid, as suggested by Mikulicz, or of nucleate of soda, as suggested by Hanner, would also seem to possess some merit.

Not infrequently the infection becomes localized on one, generally the left, or on both sides of the uterus. I have operated in 5 such cases; in 4, single abscesses were found on the left side, within the tube or bounded by the tube, omentum, and knuckles of small intestine. In 1, abscesses were found, one on each side. The date of operation was from the eleventh day to the tenth week after confinement. All but one recovered. The later the abscess develops, the better the prognosis. The fatal case was the one operated on the eleventh day.

Puerperal Eclampsia.—Incision of the kidney capsule, or "capsulotomy," may prove to be of great service in puerperal eclampsia associated with scanty or suppressed renal secretion. The idea originated with Reginald Harrison.[63] It is quite in harmony with principles applied elsewhere, as, for instance, in glaucoma, where the relief of

tension arrests the degenerative changes and preserves the sight. By this means von Graefe converted an incurable affection into a curable one. There is a condition of renal hyperemia which may be termed renal glaucoma. Dickinson[63] mentions one instance in which such extreme congestion and intracapsular tension occurred in nephritis that the kidneys burst through their capsules.

Delafield mentions extravasations of blood in the Malpighian bodies, the tubes, and the renal tissue, and the presence of coagulated fibrin in the tubes. Pinard[65] would commend nephrotomy in the treatment of anuria occurring in women suffering from eclamptic attacks, and notes that in Edebohls' cases and in that of Chambrelent and Pousson it was decapsulation of the kidney in patients in whom there was suppression of urine, as well as eclampsia, that proved so successful. Many women, however, die of eclampsia without suppression of urine, and yet their kidneys may be more or less diseased. Pinard[65] would not expect benefit from capsulotomy in such cases.

Of course, both kidneys may be congested, but the relief of tension in the one kidney aids recovery in the other.

Harrison[64] prefers to incise along the convex border, unless there are indications to the contrary. Congestion and extravasations of blood are not always uniformly distributed. Punctures may be made wherever the engorgement is greatest, avoiding always the pelvis. A drainage-tube should be left in position for a few days.

The Pyelonephritis of Pregnancy.—The etiologic relationship of pregnancy to pathologic changes in the ureters, pelvis of the kidney, and kidney is still debatable. On the one hand is the view held by Opitz,[67] who collected 84 cases from literature, that the pyelonephritis of pregnancy is the result of obstruction to the flow, due to pressure on the ureter plus infection through systemic channels or from the lower urinary passages, and, on the other hand, the view so clearly advocated by Reed,[66] that it is an exaggeration of the kidney of pregnancy, which, in turn, is due to changes in the renal epithelium and parenchyma resulting from the transudation or excretion of the toxins of pregnancy through the renal tissues plus bacterial infection, probably of vesical origin. In puerperal cases Vinay[68] assumes the presence of crushing injuries and hyperemia during labor.

The disease may develop as early as the fourth or fifth month, when pressure would seem improbable. Neither theory satisfactorily explains the predominance of the condition on the right side. Pyelonephrosis demands drainage, before or after the inception or completion of gestation, according to the date of its recognition and the urgency of the symptoms.

Catheterization of the ureters aids in the diagnosis.

THE SURGERY OF VACCINATION AND VACCINIA.

It would seem, theoretically, that the antiseptic treatment of wounds should preclude the possibility of the tetanus or other bacilli remaining

active in them. In the great majority of cases this is true. It is particularly true of tetanus when, in addition, an inhibitive quantity of antitetanic serum is given at the time of the first dressing. Nevertheless, every year a number of cases develop after injuries from explosives, fireworks, toy pistols, etc. This is, for obvious reasons, especially important when following the minor operation of vaccination. How often the infection is contained in the vaccine lymph is uncertain. At the time of its supposed occurrence in some of the Atlantic cities, tetanus was observed as well in a number of children not recently vaccinated. It would seem to be unknown in Continental countries as a complication of vaccination.

In doing that little operation, the protective epithelium is removed, and an open door is left for the tetanus or any other bacterium to gain entrance. The same is true of all wounds, burns, etc.

Cellulitis, adenitis, ulceration, localized vaccinal gangrene, erysipelas, septicemia, and pyemia may all be prevented by surgical cleanliness. Only those working among the poor in large cities and in the outpatient departments of large hospitals know how difficult it is successfully to preach the gospel of cleanliness. The wonder is that, in spite of the care of the doctor and the use of shields, more pyogenic and other infections do not occur. The percentage of infection is, nevertheless, infinitesimal, although not insignificant. In Germany there were only 113 deaths in 32,000,000 vaccinations, or 1 in 283,177, and 46 of these were traceable to the carelessness of the patient—a small price to pay for the immunity conferred.

In the treatment of vaccinal complications there is nothing special. At the very earliest appearance of symptoms of tetanus all the infiltrated tissue should be thoroughly excised, the wound soaked with peroxid of hydrogen for twenty minutes, and bathed with sublimate solution, 1 : 1000, followed by the same, 1 : 3000, and antitetanic serum injected on the proximal side of the lesion. In Mixter's case this technic was quite successful.

THE SURGERY OF SCARLET FEVER.

The complications of scarlet fever in which the advice and coöperation of the surgeon may be sought are numerous and important, often demanding the exercise of mature judgment, prompt decision, and considerable resource.

The same may be said of ulceration appearing on the tonsils. The ulcerative stomatitis, promptly recognized and appropriately treated, can usually be brought under control. More difficult is the treatment of noma, which is more common when scarlet fever succeeds measles.

The extensive adenitis and peri-adenitis seems to be inhibited somewhat by the continuous application of an ice-bag. It is certainly soothing and grateful during the first forty-eight or seventy-two hours, when, if suppuration seems inevitable, it should be replaced by hot fomentations or a good thick hot linseed poultice. When pus forms,

a small incision and drainage are sufficient, especially when supplemented by the suction-cups of Bier.

The joint affections, the so-called scarlatinal rheumatism, involving by preference the smaller joints and the upper extremity, are usually relieved by rest and cold or heat. Whenever effusion takes place, accompanied by increased temperature, the exploring needle should be used to demonstrate the character of the fluid, which should also be examined bacteriologically. If purulent, no time should be lost in making one or two incisions, through which the pus may escape and the joint be irrigated. Caiger[70] speaks highly of injecting, to the point of distention, a solution of carbolic acid 1 : 20. After it is allowed to escape, the openings are closed by gauze soaked in collodion and firm elastic pressure applied by means of alembroth wool and bandage, and the limb placed upon a splint. This treatment was entirely successful and no re-collection of pus ensued. Gentle passive motion was allowed at the end of two or three weeks, and a sound joint was a result in all. The salicylates are useless.

In regard to the acute nephritis occurring in scarlet fever, this much may be said, that if, in spite of the usual remedies, the urine lessens in quantity until a condition approaching anuria obtains, renal capsulotomy would be justifiable, logical, and advisable, barring contraindications. The hot-air or steam bath, dry or wet cupping, probably acts by relieving the blood-pressure in the renal vessels. Capsulotomy is certainly a more direct and effective means of attaining this result, and while attended by obvious objections, should be given a free trial in cases that are going down and in which the freezing-point of the blood is low. In the anginose form, incision through the skin relieves tensions, provides drainage by oozing, and inhibits the formation of sloughs which, in separating, have caused fatal hemorrhages from large vessels. In some cases even the carotid has been opened.

THE SURGERY OF RHEUMATISM.

The investigations regarding the nature of rheumatism have been of more than passing interest to surgeons, particularly the question of its resemblance to an attenuated pyemia. The sweats, the temperature curve, the involvement of serous membranes, and the anemia resemble an acute infection.

Cole claims to have produced in rabbits, by injection of streptococci, articular and endocardial lesions similar to those found in rheumatism. Beattie could not confirm these experiments. On the contrary, he found that when he injected into rabbits the micrococcus obtained from a rheumatic fever patient, joint lesions and sometimes endocarditis occurred, and the animals frequently recovered. When, however, he injected pyogenic streptococci, the joint lesions were suppurative, endocarditis rare, and the animals generally died. Beattie's[74] experiments would seem to harmonize with clinical observation and demonstrate the specific nature of the infection in articular rheu-

matism. Undoubtedly, pyogenic organisms have been obtained from the joints in the severer type of articular rheumatism, but are they to be regarded as a normal accompaniment of the disease, a constant etiologic factor, or a complication? Instances of arthrectomy, lavage, and drainage, followed by amelioration of symptoms and cure, have been reported. This heroic treatment may well, for the present at least, be reserved for those intensely severe cases that do not yield to internal medicine. In such cases, when the effusion is found to contain staphylococci or streptococci, and is purulent, there should be no delay in evacuating the fluid and washing out and draining the joint. It should be done, moreover, under the most rigid and perfect technic possible.

The Bier treatment by hyperemia has been found useful, more especially in the acute forms.

THE SURGERY OF MUMPS.

Suppuration being rare in the epidemic parotitis known as mumps, the surgeon is seldom called upon to interfere. The metastatic involvement of the testes and ovaries, especially about the age of puberty, is well known.

Hutchinson reports 2 cases in which traumatic orchitis was followed by mumps, and asks the question, "Do the parotid and testes, when inflamed, develop elements which are mutually infective?"

Parotitis occurs in a little less than 1 per cent. of cases, the infection reaching the gland through the duct or in the blood-stream. It is thought to be less frequent since the importance of frequently cleansing the mouth has been generally recognized. In the suppurative cases the typhoid bacillus may be found in pure culture, or, as is more common, in association with the staphylococcus or streptococcus, or the latter two alone. Fortunately, suppuration is rare, but if threatening, early incision is advisable. In a few instances there has been extensive necrosis of the gland, with resulting disfigurement. The facial nerve may be paralyzed.

Suppuration is usually, but not always, unilateral. It is attended by the usual symptoms, and must be regarded as a serious complication.

The employment of passive hyperemia as a therapeutic agent and as a preventive measure against the occurrence of suppuration is certainly worthy of consideration. When pus has formed, a small incision, followed by dry cupping, should prove efficient. A similar infection may occur in the submaxillary glands, but here it is of less serious import.

THE SURGERY OF MEASLES.

The chief interest to the surgeon in measles lies in its rôle as an etiologic factor in cancrum oris, noma, or gangrenous stomatitis. It would seem that catarrhal inflammation of the mucous membrane of the mouth, almost invariably present in the prodromal and early stages of measles, paved the way for secondary infections. No single

germ is constantly present. Under favorable circumstances, and also in lowered conditions of the system alone, it would seem that more than one germ may be capable of producing gangrenous stomatitis. Among the more important and virulent are the streptococci, staphylococci, and Klebs-Löffler bacilli.

Blumer and McFarlane believe the disease due to a thread-like organism of the leptothrix type, and would exclude the diphtheria bacilli as a cause or factor. Antitoxin has not proved to be of value in the treatment of the condition and is not indicated. Membranous laryngitis is a much-dreaded complication. It is generally due to streptococci, but the differentiation from diphtheritic laryngitis can be made only by bacteriologic examination.

THE SURGERY OF DIPHTHERIA.

The chief surgical interest is in the obstructive dyspnea. This, though usually due to stenosis of the larynx, is occasionally the result of extension of the disease to the pharynx, with the formation of a pharyngeal abscess, or into the trachea and larger bronchi. It is thus apparent that varied measures are needed to meet varied conditions. The relative efficiency of tracheotomy and intubation would seem to be fairly well determined. Each is particularly adapted to certain conditions. In a general way it may be said that intubation, together with antitoxin serum treatment, is giving results hitherto unattained by any other method, yet, particularly in Germany, intubation has attained its present status only after a considerable and varied fluctuation of opinion in the estimate of its relative value. The lower level of the tracheotomy tube, the larger opening, and the greater facility afforded for the extraction of loose and detached portions of membrane are advantages not readily passed by, yet against these advantages must be placed the occasional ulceration of the anterior wall of the trachea from the pressure of the lower end of the tube or the posterior wall from the pressure of the convexity of the tube, objections, however, which may be largely overcome by careful adaptation of the tube in size and form. The swelling around the lower end of the tube may in itself be obstructive, and the granulations springing from the decubitus ulcer may be sufficiently exuberant to obstruct the lower end.

Koenig[75] mentions an instance of a child dying of hemorrhage from these granulations, the immediate cause being the reintroduction of the tube, after cleaning, by the parents. It must be admitted also that a very considerable number of children have died from extratracheal hemorrhage during the performance of the operation of tracheotomy. In addition to this, one must consider the phlegmonous processes that may arise from infection of the wound, the cartilage necrosis, and the fistulæ which develop when the tube remains too long a time and the mucous membrane and skin unite. These complications must not be disregarded in forming a comparative estimate of the value of tracheotomy.

One of the great advantages of intubation is its freedom from the objections of a cutting operation. For this reason the consent of the parents is much more readily obtained, and, therefore, it may be used before the general condition of the child has been materially impaired by the imperfect aëration of the blood. Very seldom does any injury result from the insertion or removal of the tube, as in tracheotomy, but a decubitus sore occasionally develops, and more commonly on the anterior wall. In only rare instances is the intubation followed by necrosis of cartilages and stenosis. In Germany intubation has now the support of Bokai, Ranke, von Muralt, and Kroenlein. According to Ranke, 41 per cent. of cases of primary diphtheria of the larynx have recovered after intubation, as against 32½ per cent. after tracheotomy. The earlier use of the tube and its employment in milder and less extreme cases may quite possibly have contributed to the better results obtained after its use. The better results from intubation have been largely achieved since the introduction of the serum. In fact, it is impossible to get a large series of cases for comparison with tracheotomy before the introduction of serum as a therapeutic agent. It is quite clear that antidiphtheritic serum and intubation together give better results than were ever obtained by tracheotomy and other forms of treatment, and it is also clear that intubation and serum together are giving better results than tracheotomy and serum. Trump collected from 56 physicians 5468 cases of intubation, with 36 per cent. of cures before the serum period, and 81.98 per cent. of cures after the introduction of serum in the treatment.

THE SURGERY OF WHOOPING-COUGH.

Intubation in the treatment of pertussis has been employed by Saunders[76] in one case, and, it is said, with flattering results.

THE SURGERY OF PLAGUE.

Plague presents many features of interest to the surgeon other than its long and ancient history of conquest and destruction. The demonstration of the cause of the disease by Kitasato and Yersin in 1894 must rank as one of the most important discoveries in bacteriology. It suggested that, in the bubonic variety at least, the disease was communicated by local infection, and the enlargement of the nearest group of lymphatic glands, in the groin, axilla, or elsewhere, and the frequent involvement of the femoral group, harmonised with this view. Marshall[77] says that the point of entrance can frequently be determined to have occurred through wounds, pricks, bites of insects, etc., usually on the feet, legs, arms, and hands; that sometimes small red spots mark the point of infection and become successively vesicles and pustules; and, furthermore, that a series of vesicles may mark the passage of the infection along the lymphatic vessels. Nevertheless, removal of the glands has not contributed much to the progress of recovery. The point of

infection can be found in only a minority of cases, and evidence of the spread of the infection along the lymphatics is more often conspicuous by its absence. It would seem that the disease may enter by a wound in some cases, but may also enter by the respiratory passages and by the food. In the bubonic form enlargement of the glands, as described by Cantlie, is sometimes accompanied by a marked edema of the adjacent tissue, over an area of five or six inches, the whole forming an elevated doughy mass. Over such masses hot poultices are grateful, and when suppuration occurs the pus, which contains bacilli, should be evacuated. This is often followed by a general improvement. The technic should be perfect, else a mixed infection may occur and a general septicemia. In other cases the overlying skin becomes red and finally gangrenous, breaking down and leaving a condition resembling a boil or a carbuncle. Here, as in other glandular infections, incision and drainage give better results than excision or incision and curettage, which often carries the infection to surrounding healthy tissue. The petechiæ, purpuric patches, and ecchymoses, the epistaxis, the hematemesis, melena, and hematuria occasionally observed, are evidences of alterations in the quality and coagulability of the blood. Indeed, the French physicians in Egypt in 1835–36, when bleeding was customary, noted that the blood coagulated imperfectly and did not form the usual buffy coat. The success obtained by Yersin and others with the serum, both as a therapeutic and prophylactic agent, has been so great that all other remedies are relegated to the background. Wright and Windsor, using methods of high precision, have shown that normal human serum is devoid of bactericidal action on the Bacillus pestis. Papules may appear, starting as a red or brown spot, accompanied by a burning sensation. They sometimes enlarge, become indurated, and vesicles develop, which contain plague bacilli in numbers. When the vesicles are invaded by ordinary cutaneous microörganisms, the contents become pustular. Hunter[78] regards these cutaneous eruptions "as evidences of local growth of the Bacillus pestis, similar to that found in enteric fever where the typhoid rash is the result of focal multiplication of typhoid bacilli." The vesicles and pustules are to be regarded rather as an evidence of the blood infection and of the septicemic nature of plague than as points of entry of the infection, although the latter may be the correct interpretation in some cases. The bubo, also, is more commonly an evidence of infection of the blood, occurring frequently in lymphatic glands not in direct connection with the area of the skin through which the infection is supposed to have occurred. Often it is the deep and not the superficial glands that are affected, as, for example, the iliac lymphatics. The surgeon when operating on these cases should wear rubber gloves himself and insist upon his assistants and all the nurses associated with the case wearing them as a protection against infection.

THE SURGERY OF SCURVY (SCORBUTUS).

That scurvy was the result of an infection was first suggested by Torup in 1877. Torup thought it came from the use of decomposed food, bad hygiene, and unsanitary surroundings—in other words, a form of ptomain poisoning. Babes[72] thinks it the result of a specific infection, and this view has many adherents. Babes succeeded in producing in rabbits many of the characteristic features of scurvy by injecting them with cultures taken from the gums of patients suffering from the disease, and describes a bacillus which he believes to be the cause of scurvy. The experience obtained during the siege of Paris favored the infection theory, and Coplans observed, during the Boer War, that those camps that were kept in good sanitary condition were comparatively free from scurvy, while it was prevalent in those camps where favorable hygienic conditions did not obtain, although the food-supply was the same. He has demonstrated the importance of the local treatment of the gingivitis.

In the case of infants, in whom, about the age of eight or ten months, the disease sometimes occurs, the infectious origin is not so apparent, as in the absence of teeth the gums are but little, if at all, altered. Certain it is that in children, as in adults, a diet of fresh food and the organic salts of potash is followed by the happiest results.

The deep subcutaneous hemorrhages are tender, painful, pit on pressure, and the overlying skin is discolored. They may occur without trauma, a point to be remembered in medicolegal cases. Under rest and gentle massage they usually disappear.

Thick-bordered ulcers sometimes result from slight trauma and may extend into vessels and give rise to serious hemorrhages. Gangrene of the lung, if localized, might be treated surgically.

The joint condition in infants has been frequently mistaken for rheumatism—a disease rare under two years of age. Hemorrhages may occur into the joints, the pleura, or pericardium.

The question of the lessened coagulability of the blood is perhaps not yet definitely settled. If it ever occurs, it does so but rarely.

Hemorrhages occur beneath the periosteum, particularly of the femur and tibia; seldom beneath that of the bones of the arms. If near the epiphyseal line, they may be mistaken for osteomyelitis or epiphysitis. It should be differentiated from the latter by the absence of fever and by its diffuseness. It is usually absorbed under constitutional treatment. Fractures of the femur and tibia sometimes occur in infants, and occasionally separation of the epiphysis.

The essential treatment is dietetic and hygienic.

Many of the surgical complications of scurvy, influenza, small-pox, varicella, and whooping-cough, including arthritis, gangrene, abscess, and nephritis, have been referred to in speaking of similar conditions associated with typhoid, pneumonia, rheumatism, and pneumococcus infection, and but little more need be added.

THE SURGERY OF INFLUENZA.

The influenza bacillus has a special aptitude for inducing thrombosis, both arterial and venous, as demonstrated by Flexner. Thrombosis is more common in epidemics and severe cases, and generally appears about the time of the crisis. The femoral vein is more commonly affected. The condition is not serious, but, relatively speaking, is benign and of short duration.

Small pulmonary abscesses sometimes occur. Several may unite and form one of some size. The pleura may become infected and an empyema develop.

Pulmonary gangrene also occurs. It is recognized by the usual signs and the presence of elastic tissue in the sputum.

Surgical treatment, when indicated, should be followed by favorable results. One case of spondylitis following influenza and going on to suppuration has been reported. The entire arch of the fourth thoracic vertebra was found decayed (Fluss[37]).

THE SURGERY OF SMALL-POX.

As might be expected, the numerous foci of suppuration in the later stage of the disease may give rise to boils and abscesses. The boils may arise from infection from the pustules or through the hair-follicles. Fortunately, deep abscesses are rare. When one remembers that the pustules usually contain streptococci, it is surprising that erysipelas is so seldom seen as a complication.

There is occasionally a metastatic purulent inflammation of the joints, especially in children, and particularly of the elbow-joint. When it occurs drainage and antiseptics should be employed promptly.

Thanks to modern nursing, bed-sores and gangrenous areas of skin are mostly matters of history.

Councilman[73] reports that "noma following acute parotitis was seen in 3 cases in the Boston epidemic."

THE SURGERY OF VARICELLA.

The complications of varicella are often of more immediate interest to the dermatologist than to the surgeon. An ailment usually classed as "minor" may develop severe constitutional symptoms, high fever, septicemia, and pyemia. Varicella gangrenosa (Hutchinson[71]); "dermatitis gangrenosa infantum". (Crocker); ecthyma térébrant is one of the most important of the cutaneous complications. Mr. Hutchinson states that it is not connected in any way with debility on the part of the patient, but rather with idiosyncrasy in reference to the specific poison. In extreme cases the whole body from the head to the foot has been covered with gangrenous areas.

A similar condition may occur at the site of vaccination, in association with hydroa, miliaria, or any cutaneous lesion with abraded epithelium and open doors for infection to enter. It has been thought

by some that it occurred especially in children the subjects of rickets or tuberculosis.

In other cases the infection may perforate the deep fascia, particularly about the scalp, beneath the occipitofrontalis aponeurosis. Staphylococci, streptococci, and pneumococci predominate. In the treatment one might consider the use of small incisions, followed by the Bier cups, and the opsonic treatment of Wright.

Erysipelas has appeared in a few cases and proved fatal.

In addition to the usual remedies, incision, suction-cups, and the opsonic treatment are indicated in suitable cases. No satisfactory explanation has been offered to explain the common exemption of the four extremities, the disease being confined to the face, head, and trunk.

THE SURGERY OF DYSENTERY.—(See Vol. IV., p. 1101.)

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CHAPTER LXXXIII.

THE USE OF THE *X*-RAY AND RADIUM IN SURGERY.

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INTRODUCTION.

In May, 1900, a committee of the American Surgical Association, after discussing the medicolegal relations of the *x*-ray, made the following statement: "The technicalities of its production, the manipulation of the apparatus, etc., are already in the hands of specialists, and with that subject also it has not seemed worth while to deal. But it is earnestly recommended that the surgeon should so familiarize himself with the appearance of skiagraphs, with their distortions, with the relative values of their shadows and outlines, as to be himself the judge of their teachings, and not to depend upon the interpretations of others, who may lack the wide experience with surgical injury and disease necessary for the correct reading of these pictures." To-day this recommendation is more than ever worthy of acceptance, and in the following chapter the writer has aimed to omit technicalities and, instead, to discuss only those accepted facts and general principles with which every student and practitioner of surgery should be familiar.

The discovery of the *x*-ray was announced by Professor Röntgen in a paper before the Physico-medical Society at Würzburg in December, 1895. The rapidity with which the whole world took advantage of this new agent is a good illustration of the power of modern science. Within the next year it was the common property of the medical profession, and was in practical use for diagnosis in every large city and in many of the smaller towns throughout the civilized world, and yet the year before a form of light which could penetrate opaque objects and never undergo refraction was absolutely unknown in nature and almost unthinkable philosophically. It seemed at first extraordinary that the *x*-ray should easily traverse wood and that glass was relatively opaque to it. Now, however, so much does familiarity take away wonder, that the *x*-ray worker thinks it quite as remarkable that ordinary light manages to get through dense glass as that *x*-rays should penetrate wood. And, after all, is it not even more simple to imagine a light which penetrates any object and all objects in straight lines and is only checked in proportion to the density of the object, than to imagine a light which passes directly through some dense materials,

but which is twisted about, reflected and refracted by other materials in different degrees according to the texture and contour of the material and not according to density?

Physical Experimentation Leading to the Discovery of the x-Ray.—As must always be the case in a truly scientific discovery, Röntgen must share his glory with the workers in the same field who have prepared the way for him. In this instance the two essential factors for the production of the *x*-ray were two previous scientific inventions which were practically unknown except in laboratories—the high-tension electric discharge and the vacuum bulb. A long series of electric experimentation had led to the production of a convenient form of apparatus known as the Ruhmkorff coil for producing a high-tension discharge. Such coils were to be found in every physical laboratory. Another series of experiments had led to the production of glass bulbs or tubes from which the air had been exhausted to varying degrees of vacuum. These bulbs were used by physicists to demonstrate certain phenomena produced by the passage of high-tension currents of electricity through different gases in various degrees of rarefaction. Bulbs or tubes of this kind were also in every well-equipped laboratory and were not infrequently experimented with. Crookes (by whose name these tubes have since been called) had shown that at a certain degree of vacuum the transmission of such a current through a tube containing two metal terminals which he called anode (+) and cathode (−), was capable of exciting another discharge which radiated in all directions from the cathode. He made many most interesting observations on the character of this discharge, which came to be called cathode rays. Among other facts he showed that these rays proceeded in all directions from the surface of the cathode, and could, therefore, to a certain extent be focused by shaping the cathode like a concave reflector. When they were thus focused, he demonstrated that, at the point of their impact on any object inside the tube or on the wall of the tube, their energy was transformed into heat and light. Shortly afterward Lenard, while repeating these experiments, showed that the effects of the cathode rays, or some closely allied rays generated by the excited tube, were capable of demonstration outside the tube. Lenard's experiments brought him to the verge of the discovery of the *x*-rays, but it remained for Röntgen to observe that, besides heat and light, rays (which he called *x*—*i. e.*, of unknown nature) were also generated.

PHYSICAL PROPERTIES OF THE *X*-RAY.

It is greatly to Röntgen's credit that his original announcement of his discovery was so thorough and his description of the physical properties of the rays so complete that other physicists have been able to add but little since. In brief, his experiments showed that, when a Crookes' tube was excited, besides heat and light, certain rays were generated at the point of impact of the cathode rays. The new rays were invisible, radiated in straight lines from their point of origin, and

PLATE III.

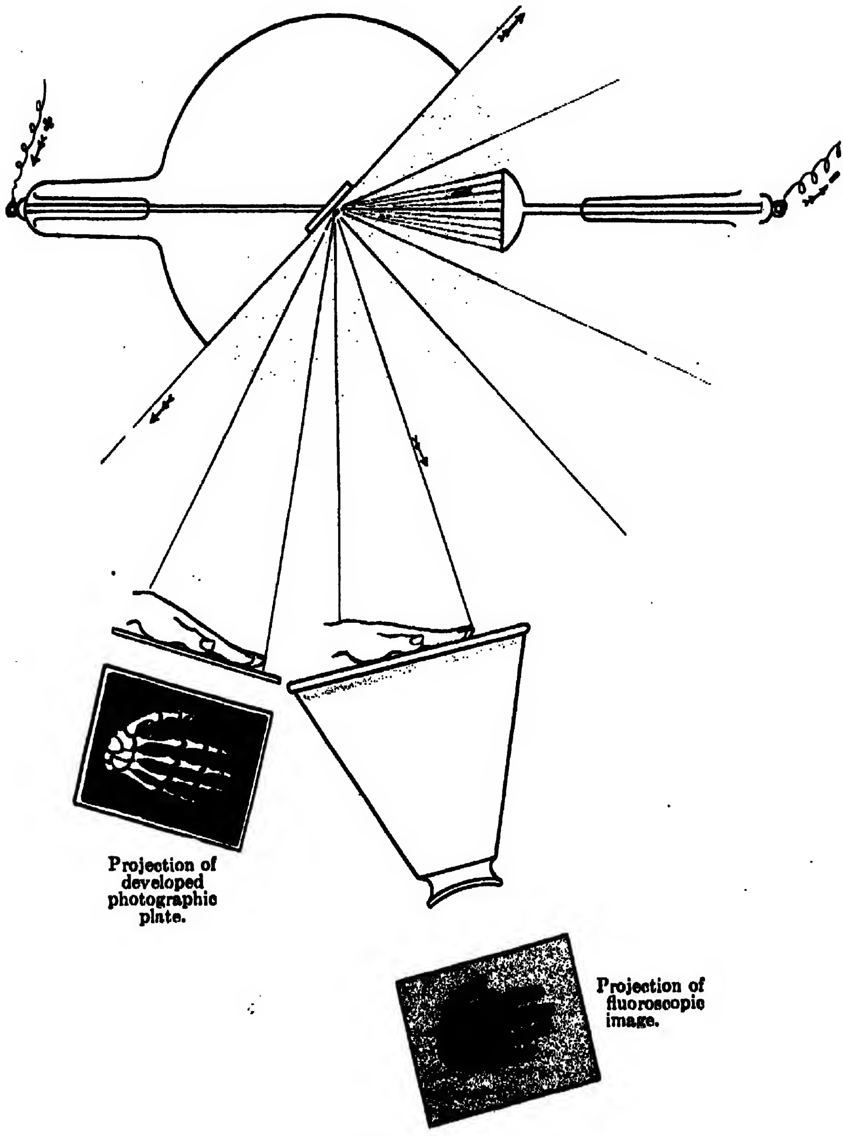

DIAGRAM OF CROOKES'S TUBES ILLUSTRATING ANODE, CATHODE AND FOCUS POINT, AND THE PATHS OF THE CATHODE RAYS AND x-RAYS.

In the paths of the x-rays are shown a diagram of a fluoroscope with the projection of the shadow of a hand and also a diagram of a plate in a plate-holder with the projection of the shadow of a hand: Red, focus point and paths of x-rays; blue, paths of cathode rays; yellow, barium platinocyanid screen with projection of bones of hand; green, fluorescence of glass excited by x-rays.

could not be reflected, refracted, or otherwise turned from their paths by the interposition of sheets of black cardboard, blocks of wood, thin layers of metal, or any other substance at his command, although their effect was diminished according to the amount and density of the substance interposed. Their existence was proved by the fact that they had the power of producing fluorescence of certain salts (in a dark room) and of producing changes in a photographic film similar to those produced by ordinary light. Among the salts in which fluorescence was produced, barium platinocyanid appeared to be the most sensitive, and a sheet of cardboard washed with this salt he used as an indicator of the presence of the rays. He found that dense objects interposed between the tube and this cardboard cut off the rays behind them, thus leaving a portion of the barium platinocyanid, corresponding to the shape of the dense object, more or less unexcited to fluorescence. The effect produced would correspond to a shadow or silhouette of the object, since the part of the screen unprotected by the object would fluoresce in contrast to the protected part. This screen was the prototype of the fluoroscope, which is merely a similar fluorescent screen inclosed in a convenient light-tight box. (Plate III.)

Röntgen controlled and recorded his observations on the fluorescent screen by also using a photographic plate in its place. In a similar manner dense objects protected parts of the film from the action of the rays, and when the plate was developed, the silhouette of the object appeared contrasted to the parts of the film unprotected from the action of the rays.

When, among other objects, he exposed the human hand, the developed plate naturally indicated the outlines of the bones, since, being more dense, they allowed less rays to pass than the fleshy tissues. This experiment was the beginning of the science of skiagraphy or radiography; x-ray pictures are to day taken in essentially the same manner as described by Röntgen, except that increased experience in the making and management of the apparatus has made it possible to make these pictures with almost mathematic accuracy. The forms of apparatus which produce the high-tension current are now controlled so readily that the discharge is delivered to the tube with the greatest precision and speed. The tube itself is so constructed that the degree of its vacuum can be altered at will, and the cathode rays accurately focused at one small point, thus rendering the radiating lines of x-rays more exact and the shadows they cast sharper. The technic of making and developing the photographic plates used for this work has also greatly advanced.

Notwithstanding all these improvements, however, the fundamental fact remains the same, that the x-rays cannot be reflected, refracted, or deviated in any manner from their course, and consequently cannot be focused, in the sense that ordinary light can, by lenses. The best that science can do is to make as small as possible the focus point from which they are generated. Practically, in the most perfect tube this point is now small enough to give very definite outlines, but since this

point has some width, the detail is never absolutely accurate for objects at a little distance from the plate.

In this chapter it is not thought advisable to describe the forms of apparatus in common use, since whatever their form, convenience, or price, they at best can only produce a radiation from a single point, which must give the same important advantages and disadvantages for surgical work. Indeed, the mere fact that the *x*-light always radiates from one small point in straight lines according to the absolute laws of geometric projection, makes its use really very simple when one once understands that a skiagraph is not a picture, but "a record of density, produced by the Röntgen rays, and made according to the laws of projection" (Hickey).

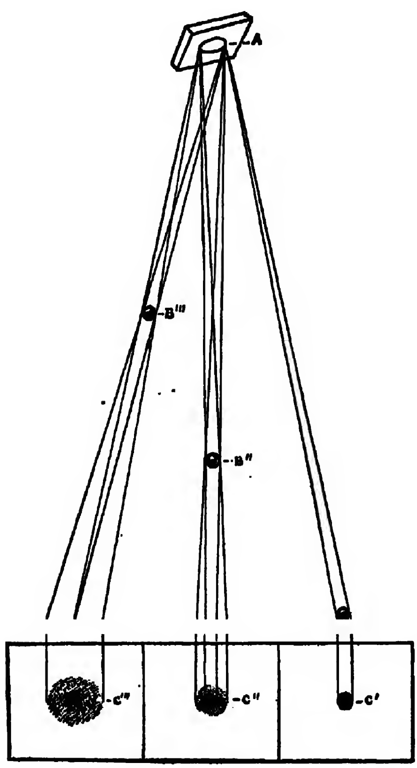

FIG. 504.—DIAGRAM EXPLAINING CAUSE OF POOR DEFINITION.

A, Focus point on anode. B', B'', and B''', objects. C', C'', and C''', projections of objects as they would appear on plates. It will be observed that the projection of B' is nearly the same size as the object, and its outlines are clear cut, while C'', C''', are greatly enlarged, their outlines poorly defined, and their density diminished.

Thus, if he wishes, the surgeon may leave to the skiagrapher the knowledge of the details of the arrangement of the whole apparatus up to the stage at which the *x*-rays radiate from one point, but beyond this he must understand thoroughly what may be expected from their use. The reader should carefully study Plate IV., which shows a few of the common causes of *x*-ray distortion. Practically, these distortions are seldom exaggerated enough to be noticeable, but are always present to a certain degree.

For convenience of expression we say that the penetration of the *x*-ray varies according to the density of an object. This is not strictly true, for the opacity of an object to these rays varies according to atomic weight, not exactly according to density. Since, as a rule, dense objects have a heavy atomic weight, we find it more convenient to speak of density when we really mean atomic weight. In some cases this does not hold—for example, the density of a substance may vary according to its physical state, whether hot or cold, solid, liquid, or gaseous, but its atomic weight and its penetrability to the *x*-ray remain constant if its quantity and volume are constant.

It is also thought best in this chapter to disregard the difference between what are called "soft" and "hard" x-rays. Under certain conditions the penetrating power of Röntgen rays varies greatly and consequently the projections which they cast also vary greatly in density. Tubes which give x-rays of low penetrating power are called "soft," and tubes which give rays of a high penetrating power are called "hard."

COMPARISON OF SKIAGRAPH AND PHOTOGRAPH.

Since a skiagraph is a record of the densities of the different portions of an object, it only in some cases resembles the picture of an object. Compare the skiagraph of the bones of the foot with the photograph (Figs. 505 and 506).

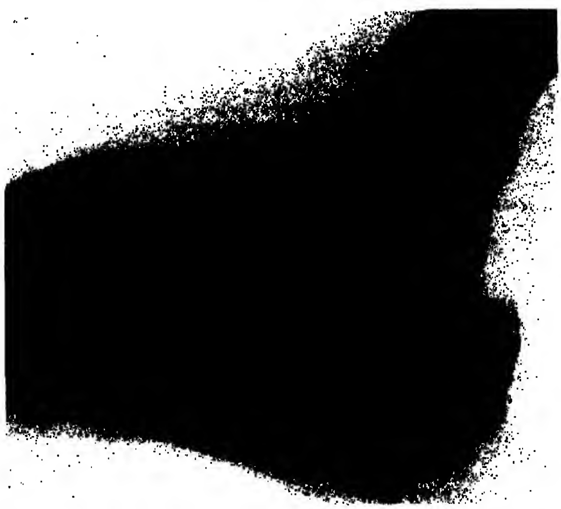

FIG. 505.—SKIAGRAPH OF NORMAL FOOT. (Compare with Fig. 506.)

The photograph gives to the mind only the data which are reflected by the surface of the bones toward the eye; on the other hand, in the skiagraph we do not see the surface of the object at all, but certain details of its internal structure are seen. In the skiagraph the arching structure of the bony fibers of the os calcis resembles—but is not—a picture of a median section. In the photograph the surface shows roughnesses which are not visible at all in the skiagraph. The outlines are present in both pictures, but in the photograph those outlines which are overlapped are not visible, while in the skiagraph both overlapping and overlapped are often, but not always, seen. Compare the os calcis in the two pictures—the outlines are about the same, but observe the astragali and look at the superior outline—in the photograph it does not show. On the other hand, in the skiagraph the tip of the external malleolus does not show.

It is from the fact that the outlines in the x-ray pictures are the same

as in ordinary pictures of the same bones that confusion has arisen, and that most people fail to understand skiagraphs.[1] As the outlines are the same, we expect them to bound surfaces or median sections instead of bounding charts of the whole bone. Look at Fig. 506 again, and notice the tibiotarsal joint. Why does it show in the skiagraph? Because the rays which pass through it meet less obstruction than those which pass above or below it. Those which are just above it meet the articular surface of the tibia, which, as it is more dense than the spongy tissue above it, is registered as a dark line. In the same

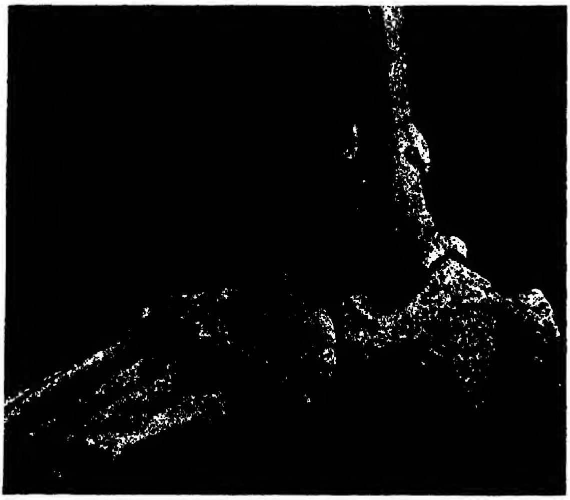

FIG. 506.—PHOTOGRAPH OF NORMAL FOOT. (Compare with Fig. 505.)

way the articular surface of the astragalus just below is registered. These outlines, of course, represent the bony outlines, and not those of the articular cartilages, which are transparent to the x-rays.

X-RAY ANATOMY.

The important conclusion to be drawn from these facts is that, to interpret skiagraphs correctly, we must be familiar with the interior anatomy of bones, as well as their surface appearances—at least, with so much of their interior as appears in the skiagraph. For instance, in the skiagraph of the os calcis which we have already taken, some portions will be observed to be lighter and some darker. The sustentaculum tali is represented by a more or less oval dark area, while just beneath it is a lighter one, representing a portion of the bone which gives less resistance to the rays. In the same way all the other bones have their more or less dense portions, and a knowledge of these portions is

[1] It is for this reason that the stereoscope and "fluoroscopic spectacles" are unsatisfactory for x-ray work. The value of the stereoscope depends theoretically on the outlines bounding surfaces. This is never true in skiagraphs; x-ray outlines also differ from ordinary outlines in point of perspective, for the nearer ones are the smaller and best defined.

essential to correct interpretation. Pathologic conditions characterized by increase of bone will show darker shadows (*i. e.*, in the print); those characterized by decrease or destruction of bone will show lighter shadows and obliteration of the finer details.

Fig. 507 illustrates a skiagraph of a number of denuded bones, reënforcing the point that the outlines are like the photograph, but that

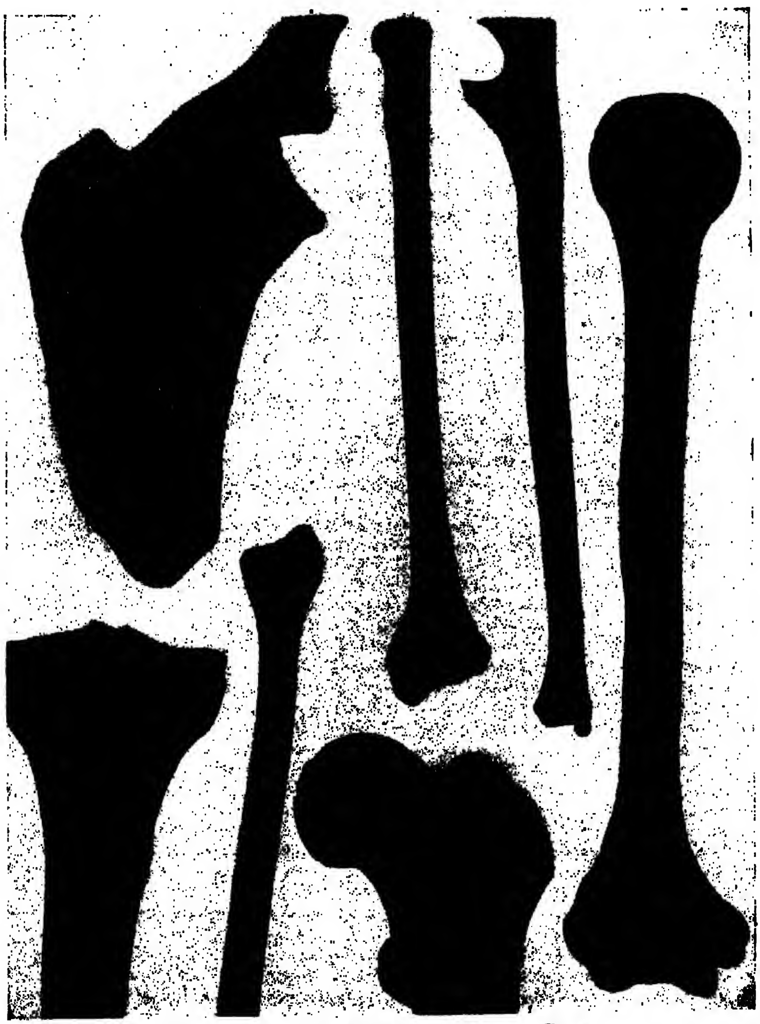

FIG. 507.—SKIAGRAPH OF NORMAL DENUDED BONES.

the picture within the outlines is a record of density, not a picture of the surface or of the median section.

Our x-ray anatomy should, therefore, comprise a knowledge of—
1. The outline. 2. The cortex. 3. The cancellous tissue and shape.
4. The medulla. 5. The epiphyseal line.

The Outline.—It is important to know the irregularities of normal outline, since certain diseases are characterized either by erosion or increase of surface bone. Occasionally the attachments of tendons are normally represented either by depressions or by prominences, perhaps by both. For instance, at the superior posterior angle of the os calcis we see a slight depression for the tendo Achillis, and at the tip of the olecranon we often find a little angle of bone projecting into the triceps tendon. It is not unusual in people of a strong muscular type to find the insertion of the larger tendons marked by these small osteophytes. The condition may be associated with osteo-arthritis, and the upward growth into the tendon be so great as to cause disability. The attachment of ligaments may cause elevations or rough, irregular depressions which must not be confused with the erosions of disease. Attention to the outline of the articular surfaces is of especial importance, for here any slight departure from a uniform outline, especially in adults, is very strong evidence of disease. In a tuberculous knee I was able to locate almost exactly the regions in which ulceration of the bone had occurred by the careful study of three skiagraphs made from different directions. The interpretation was recorded, and after excising the joint, the description was found correct in every particular.

The Cortical Bone.—A comparison of the bones in Fig. 507 will show that in different bones, and in different regions in the same bone, the cortex varies to a great degree. In the lower extremity of the radius it is indistinguishable except as outline, but as we go up the shaft it increases rapidly in thickness, reaching a maximum a little over halfway up. It is of egg-shell thinness in the square bones and the upper extremity of the tibia, etc In certain planes we may see the canals of the nutrient arteries. The importance of the study of the cortex will be illustrated in the diagnosis of hereditary syphilis.

The Cancellous Structure and the Shape of the Bone.—Shape and structure should properly be studied together, for where there are ridges or elevations, as in the borders of the fibula or the sustentaculum tali, the whole mass of the bone is projected into one plane. In Fig. 507, if we did not remember the irregular surfaces and borders of the fibula, the dark streaks in the upper part of the medullary canal might be mistaken for an increased amount of cancellous tissue in the interior of the bone. A more exaggerated example would be the olecranon fossa in the lower extremity of the humerus. If a skiagraph of the upper end of the tibia should present a similar light area, we might justly suspect an abscess-cavity. The amount of what might be called normal detail in the cancellous tissue is also important We expect to see the structure more plainly marked in the lower end of the radius than we do in the shaft of the humerus. Any localized area where the detail does not show well, while that immediately about it does not appear clear cut, suggests absorption of bone and disease; therefore, we must know where this condition normally exists (see the styloid of the radius in Fig. 507).

The Medullary Canal.—Familiarity with the normal appearance of the medullary canal of the long bones is also important, as changes in its shape are found in certain diseases.

The Epiphyseal Lines.—In studying an epiphyseal line, as in Fig. 508, we must bear in mind that the epiphyseal cartilage itself does not show. We, therefore, have the adjoining surfaces of two bones to study. If the skiagraph is taken at a slightly oblique angle, the appearance of the edge of these two surfaces will be like two irregular ellipses overlapping each other.

I have several times seen these lines mistaken for fractures. Generally, though irregular in outline, the edge is well defined and clear cut. When affected by a pathologic process, as tuberculosis, however, the detail is lost and the erosions have a distinctive character. The appearance of the different stages of normal development of the centers of ossification of the epiphyses should also be studied.

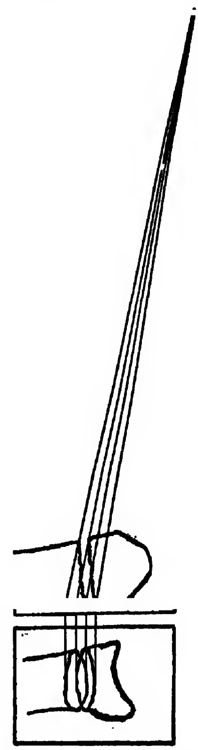

FIG. 508.—PROJECTION PICTURE OF EPIPHYSEAL LINES OF THE RADIUS.

CONDITIONS NECESSARY FOR CLEAR DETAILS IN SKIAGRAPHS.

Before proceeding to the study of pathologic conditions, a few words may be said on the conditions necessary for obtaining definite skiagraphs. For fractures and foreign bodies a very poor skiagraph is often as good as a clear one, but for the definition of diseased areas in the bone, accuracy is of far greater importance. Experience formulates the following conditions to be observed in obtaining accurate detail:

1. Keep the limb absolutely quiet in such a position that no muscular tension is required on the part of the patient.
2. Place the tube as far away from the plate as is consistent with obtaining a full exposure in a reasonable time— *e.*, usually two feet.
3. Place the patient or limb in such a position that the portion of bone suspected to be diseased shall be in the closest possible proximity to the plate.
4. Use a tube with as small a focal point as can be obtained.
5. Be sure that the plane of the plate is at right angles to the paths of the rays which strike its center.

USE IN DETECTING FOREIGN BODIES.

To surgeons who have recognized the limitations of Röntgen pictures and have appreciated the fact that they are "records of density made according to the laws of projection," the *x*-ray has been no disappointment; to others, who have lacked a clear understanding of its physical

properties, it has often proved deceitful and misleading. Mistakes in regard to the location of foreign bodies have been especially common, and have been due to inaccuracy in the technic of making the skiagraphs or of interpreting them. The error has generally been on the part of the surgeon, who has perhaps been disappointed because large pieces of wood do not show or has failed to use the x-ray for bits of glass which make very clear projections. As a general rule, objects which at once sink in water show well in contrast to the tissue; those that sink slowly or float only show if contrasted to surrounding tissues of greatly different density. Thus the lungs contrast with the diaphragm and heart, and coils of intestine distended with gas contrast with the other abdominal contents. Areas of consolidation show in the lung which would not show in the liver.

FIG. 509.—x-RAY OF THREE TEST-TUBES.
1, Containing plain water; 2, containing one corrosive tablet in solution; 3, containing two corrosive tablets in solution.

To avoid errors of localization various devices have been recommended which permit the object to be located with mathematic precision. Most of these devices, however, are so complicated in their nature that they are seldom of practical value, but in especial instances, as in locating bullets imbedded in the brain or foreign bodies in the interior of the eye, they may be of paramount importance. Some apparatus of this kind has become absolutely necessary to the ophthalmic surgeon. Perhaps the most practicable method is that recommended by Sweet, of Philadelphia. In ordinary surgery, in most instances, it suffices to carefully study the relations of the foreign body and the bony landmarks, as shown in two or more skiagraphs taken at as nearly right angles as possible. If the surgeon knows the relative positions of focus point, patient, and plate at the time the skiagraphs are taken, he should be able to locate the relation of the foreign body to the bony landmarks with sufficient accuracy. I have frequently been able to locate the plane of a bit of needle in the hand or foot with sufficient precision to cut down at right angles to it by an incision the width of a knife-blade and then with hemostatics to grasp it and force its end out through the skin. As a rule, it is better to plot out with the eye the relation of the foreign body to the bony landmarks which appear in the picture, than to attempt to locate it by the aid of metallic substances attached to the skin. Any object attached to the skin may

change its relative position as regards the foreign body, since the position of the part or the retraction on the wound shift the soft parts about to a certain extent.

In some portions of the body the anatomic conditions determine the position of the foreign body, *e. g.*, coins in the esophagus always lie in the sagittal plane, in the median line or to the left of it, whereas if they are in the air-passages, they will be found (probably in the right bronchus) to the right of the median line. If their axis lies diagonally to the vertical axis of the body, they are probably in the right bronchus

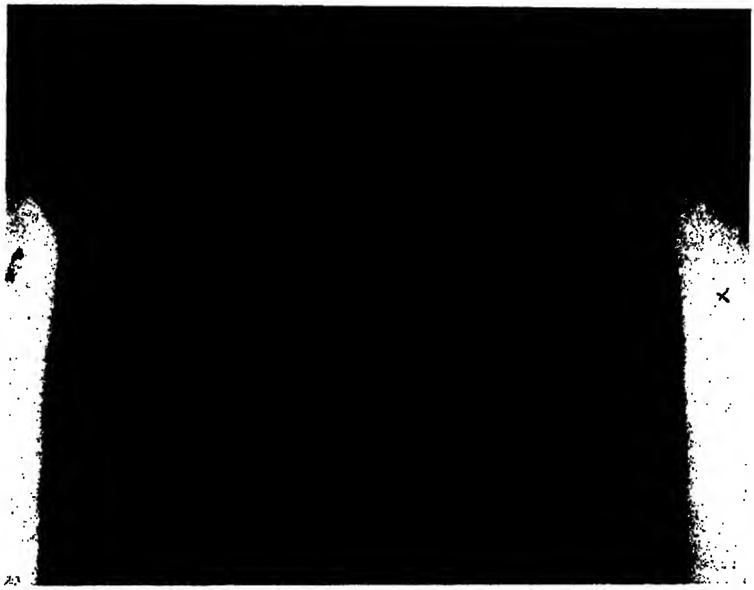

FIG. 510.—REDUCED SKIAGRAPH OF TACK IN BRONCHI.

The figure shows the position of a tack in the first primary division of the right bronchus, the point projecting about one-quarter inch into the right bronchus itself. I was able to remove the tack by introducing a urethroscope through a tracheotomy wound.

itself; if their axis is transverse, they are probably in the first primary branch of the right bronchus. A nail which was in one of the lower left primary bronchi was seen to lie with its long axis vertical.

RENAL AND URETERAL CALCULI.

One of the most important branches of skiagraphy is its use in the location of renal and ureteral calculi. It is in this branch of the work that excellence of technic is of the utmost importance. No surgeon should be satisfied with a skiagraph taken to determine the diagnosis of such calculi, unless its detail throughout is sufficiently clear to show definitely the entire outline of the last rib, for even small stones have about the same density as the twelfth rib, and should show as easily as it. The ureteral and pelvic regions should strictly demand greater detail than the renal regions. Plates of these regions cannot be too clear, for errors in both the positive and negative diagnosis are not infrequent.

In stout people clear pictures are sometimes almost impossible, and thus small calculi may escape detection. In others a heavy mass of dense inflammatory tissues about the diseased kidney may obscure the picture. On the other hand, positive shadows on the plate may be deceptive. The shadows of inspissated scybala, atheromatous arteries, phleboliths, calcified appendical concretions, caseous glands, and ossifications in the sacrosciatic ligaments may be mistaken for calculi. Shadows which do not lie in the known course of the ureters should give rise to suspicion. As a rule, it may be said, however, that the x-ray expert seldom makes an error nowadays either in a positive or negative diagnosis. It is the duty of the surgeon, nevertheless, care-

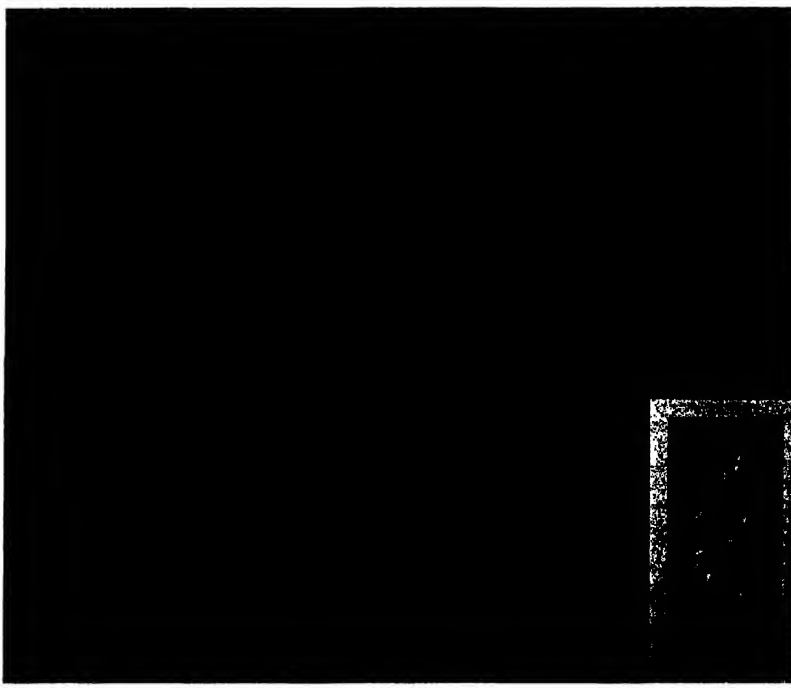

FIG. 511.—AN x-RAY AND PHOTOGRAPH OF TWENTY-EIGHT CALCULI IN THE URETER. Removed by myself by the intravesical method.

fully to study the plates and assure himself that they are definite in detail. Leonard, who has been a pioneer and leader in this branch of x-ray work, reports only nine known errors in 320 cases, but in a considerable percentage the subsequent history has not been obtained.

Before taking skiagraphs for renal or ureteral stones, the bowels should be thoroughly evacuated. A positive diagnosis should be verified by a second plate, taken at a later date. The intensity of the shadows cast by calculi varies with the atomic weight of the salts of which the calculi are composed.

Although the existence of *vesical calculi* can ordinarily be readily determined by the cystoscope and by clinical methods, the x-ray is a great boon to the patient in these cases, for its use saves the pain of the

introduction of an instrument. Occasionally, encysted stones in the prostate or in diverticula of the bladder which escape detection by the cystoscope are shown in the skiagraph.

Unfortunately, *biliary calculi*, as a rule, are of about the same density as the soft parts, and hence do not show. Occasionally one contains enough lime salts to give a faint shadow, but this is not the case often enough to make attempts to detect them in this manner of much practical value.

Calculi are exceptionally located in other glands, for instance, in the testicle, the ovaries, and the salivary glands. Caseous and calcified lymphatic nodes in any part of the body may show on the x-ray plate, since the salts of calcium are of heavy atomic weight.

In the knee-joint those loose bodies which contain lime salts (*e. g.*, chips from the articular surface known as "mice") may be expected to show in the skiagraph, while those which are composed of fibrocartilage or fatty tissue (*e. g.*, loose semilunar cartilages and synovial villi) do not show, as a rule. To render the contrast between such structures and the surrounding parts greater, Hoffa has injected oxygen into the joint with a special apparatus.

USE IN FRACTURE.

The value of the x-ray in the diagnosis and treatment of fractures has been aptly expressed by Cotton: "The greatest direct service of the x-ray in my opinion has been that it has given us a clearer idea of the lesions in ordinary fractures, and has cleared up the pathology of various less usual fractures that previously were obscure." Certainly it is true that surgeons of to-day, particularly of the younger generation, have a better idea of the pathology of most fractures than they did fifteen years ago. The ability to prove or disprove our clinical diagnoses by the skiagraph has brought greater skill in diagnosis. On the other hand, there is at present too great a tendency for the surgeon to become *dependent* on the x-ray for his diagnosis and his indications for treatment. The surgeon should not, in his desire to spare his patient, neglect to make his clinical examination as careful as possible without causing undue pain. On the other hand, after the x-ray has been taken,[1] he should not allow himself to be blinded to the clinical facts by the information it gives him. For instance, in fractures of both bones of the leg, if the general alignment of the bones is good and the fractured ends fairly approximated, it is folly to endeavor to try to obtain end-to-end approximation instead of a slight overlapping. In fact, the x-ray itself is constantly showing us bones which, although overlapped at the time the fracture was set, after a few years present only a slight jog in the contour of the bone at the point of fracture. Instances of the use of the x-ray in fractures are too numerous to mention here, and are given in the chapters devoted to these lesions.

[1] One must not look for callus to show in the x-ray until lime salts are deposited in it, *i. e.*, until it begins to be "bony" callus. This process seldom begins before the fourth week, and frequently not until many months have elapsed. Union may be firm and yet callus not appear in the skiagraph.

USE IN BONE-DISEASE.

In the early years of the use of the x-ray its evident value in cases of foreign bodies and fractures drew attention; gradually it was found that it was capable of also giving us assistance in the diagnosis of diseases which affect the bones. At first we were greatly pleased that in certain cases we were able to differentiate in a given swollen limb between fracture and disease, but gradually it became apparent that certain x-ray appearances were more or less characteristic of certain diseases. As in fractures, constant use of the x-ray has lead to a better pathologic knowledge of bone-disease. We are able, by the skiagraph, to acquire readily and easily facts which in previous times were most difficult to obtain. Even by their scanty opportunity at operation and post-mortems, our predecessors accumulated for us a vast amount of knowledge as to how different diseases affect the bones. By applying this knowledge as far as it concerns the inorganic portion (*i. e.*, the portion composed of lime salts) of the bones we may, in a given instance, use the x-ray to great advantage. It shows us, for instance, that bone substance has been lost or gained, that such loss or gain is in the shaft or epiphysis or other portion of the bone. It further shows us whether this loss or gain has occurred in any especial form—whether it has occurred irregularly or homogeneously. In this way we may gain data which are of great value as aids in clinical diagnosis. Although it is thus a great help in telling us how the disease has affected the inorganic portion of the bone, we must realize that this is all it does tell us. We cannot expect it to tell us how the surface of the bone or its cross-section looks to the eye, any more than how it smells or how it feels. The x-ray may tell us that the lime salts in a given area have disappeared and have been replaced by tissue of less atomic weight, but it cannot tell us whether this tissue is sarcoma, chondroma, hypernephroma, myeloma, gumma, pus, or clear fluid. Nevertheless, if each one of these lesions has its characteristic way of attacking the bone and causes its local destruction in a certain manner, we may infer with more or less certainty what are the contents of the space in which the lime salts have disappeared. As a matter of fact, experience has shown that these different lesions do affect the inorganic part of the bone in more or less typical ways. For instance, the effect of true medullary giant-cell sarcoma has a characteristic appearance in the x-ray, and although this appearance might be confused with that of benign bone-cyst or metastatic new-growth, it can readily be distinguished from the effect of periosteal sarcoma or of bone-abscess or gumma. As far as we know, metastatic hypernephroma and carcinoma attack the bone in a similar way to medullary sarcoma, but it is likely that increased experience will call attention to some essential point of difference which the skiagraph will register. A skiagraph properly taken is mathematically correct within a very small limit of error; it gives correct data for inference, and it is our own fault if our deductions are incorrect.

The following are certain pathologic facts concerning the usual

manner in which some of the commoner diseases affect the inorganic portions of bone, and which the skiagraph may be of assistance in deter-

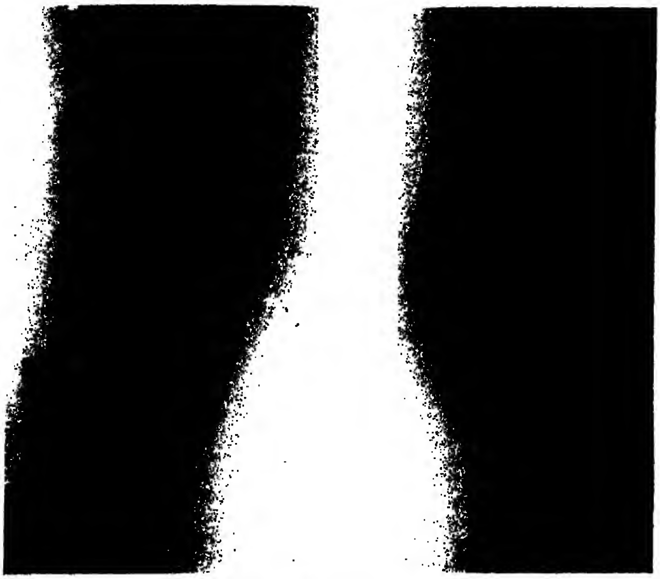

FIG. 512.—EARLY TUMOR ALBUS, SHOWING DENSITY OF SOFT PARTS AND SQUARING OF EPIPHYSIS OF TIBIA.

mining. Exceptions to these rules occasionally occur, but in the vast majority of cases of bone-disease the x-ray will give the key to the diagnosis

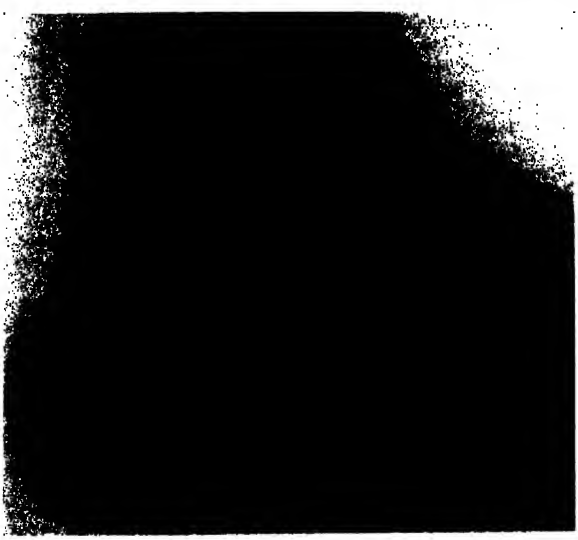

FIG. 513.—ACTIVE TUBERCULOUS DISEASE OF TIBIA.
Tarsal joint showing penciled outlines of tarsal bones.

sis to the student who combines a fair knowledge of pathologic anatomy and the simple principles of skiagraphy.

Tuberculosis *affects the joint surfaces, short bones, or epiphyses, and only secondarily runs up the shaft. Characterized by loss rather than increase of bone substance. Sequestra and abscesses are small (smaller than hazel nut) and poorly defined. Adjacent bones show atrophy.*

FIG. 514.—OLD TUBERCULOSIS OF ELBOW, SHOWING NEW BONE FORMATION AND A FOCUS WITH WELL-DEFINED WALLS IN ULNA.

In the *early stages* of tuberculosis in children the centers of ossification of the affected epiphyses are enlarged and rectangular instead of pyramidal. Trabecular structure cloudy and ill defined. Foci not definitely marked off from surrounding spongy bone. Infiltrated soft parts are more dense than normal (Fig. 512).

In *active stages* trabeculæ ill defined. Caseous detritus in surrounding tissue. Marked atrophy of surrounding bones (showing penciled outline in x-ray). Destruction may allow dislocation. Sequestra poorly defined (Fig. 513).

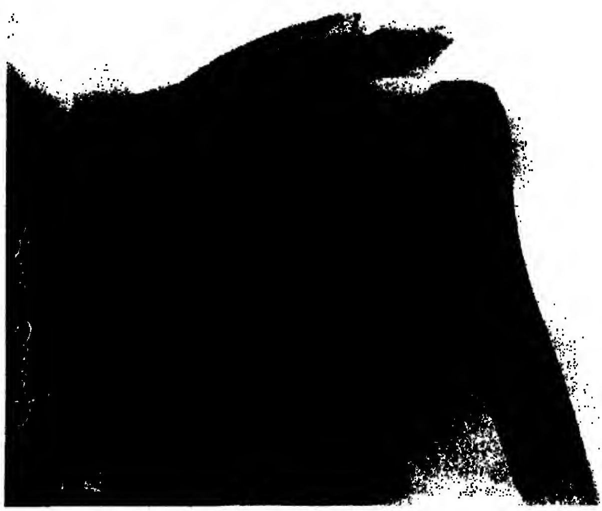

FIG. 515.—CARIES SICCA OF HUMERUS, SHOWING EROSION ABOUT ANATOMIC NECK.

In *healing stage.* Irregular compensatory new bone formation about disease. Dense and better defined walls about foci. Sequestra relatively clearly defined, often wedge shaped.

In Caries Sicca.—Local erosion of bone at margins of articular cartilage where synovial membrane is reflected. Adjacent bones not so atrophic as in usual form.

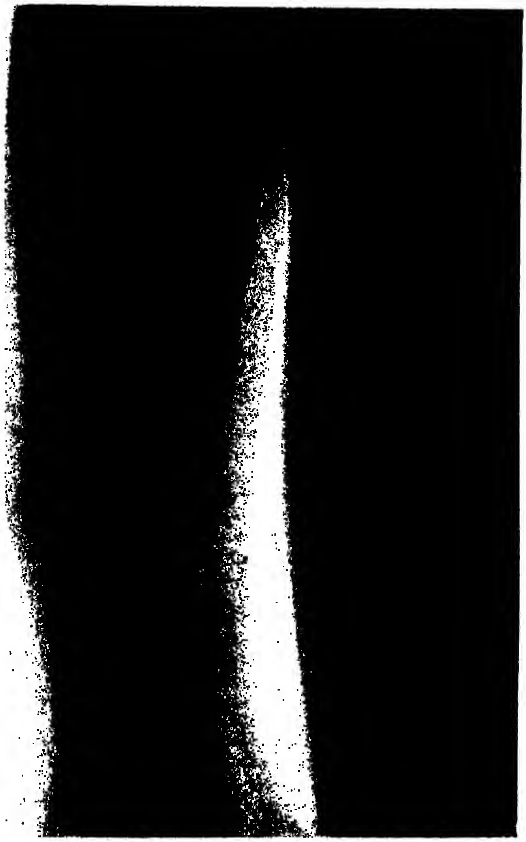

FIG. 516.—LATE FORM OF CONGENITAL SYPHILIS, SHOWING CORTICAL THICKENING, "BONE BLISTER", AND "SABER-SHAPED TIBIA."

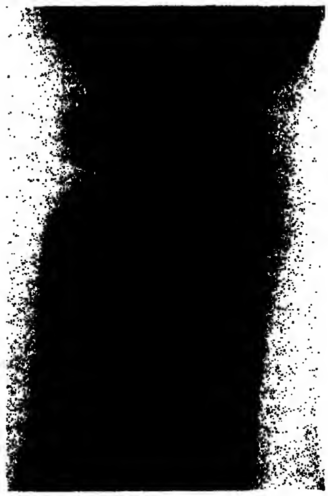

FIG. 517.—LATE FORM OF CONGENITAL SYPHILIS, SHOWING JUXTA-EPIPHYSEAL LOSS OF SUBSTANCE AND RELATIVE SHORTENING OF ULNA.

Syphilis *rarely affects joint or epiphysis, but cortex of shaft. Characterized by increase rather than diminution of bone substance. Abscesses, if any, in cortex, not in medulla. Rarely, if ever, leads to sequestration.*

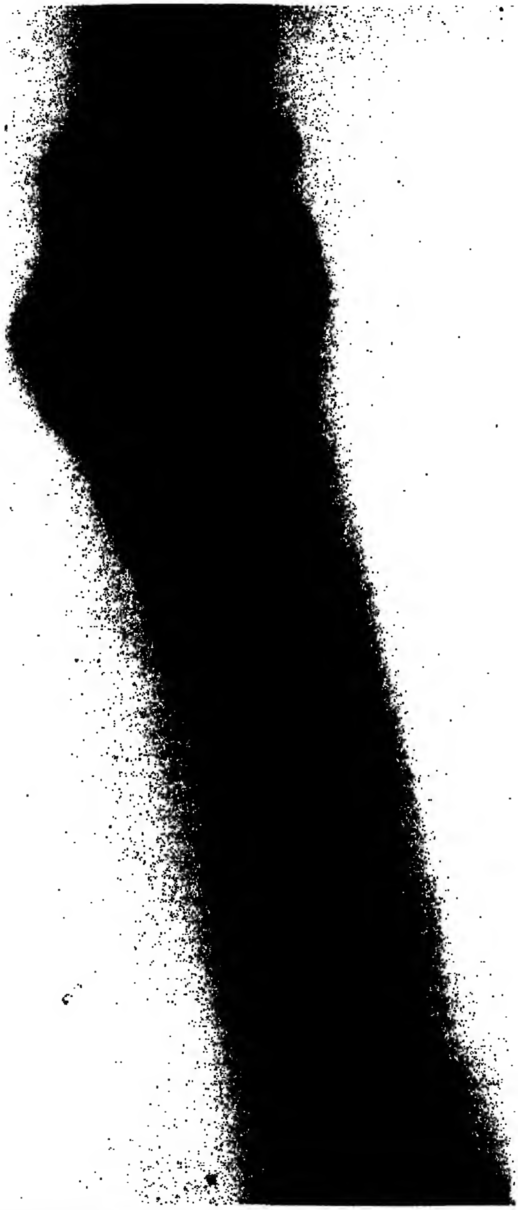

FIG. 518.—TERTIARY ACQUIRED SYPHILIS, SHOWING "FURRED" APPEARANCE OF NEW-FORMED CORTICAL BONE NEAR LOWER END OF HUMERUS.

In the *late form of hereditary syphilis* it is rare to find other bones affected unless tibiæ are also. Extreme cases give "saber-shaped" tibia, but when this condition is present, fibula also usually shows localized areas of cortical thickening.

There may be a "bone blister," due to localized gummatous formation under the periosteum. Occasionally there is localized destruction of bone substance on the diaphyseal side of the epiphyseal line, but when this is so there is also increase of cortical bone in some portions of the shaft. Interference with epiphyseal growth may cause relative shortening of ulna or radius.

In *tertiary forms of acquired syphilis* the cortical enlargement is apt to be more irregular and is commonly toward the lower ends of the long bones just above the joints. The cortical bone is deposited by the periosteum irregularly, so that the outline in the x-ray has a furred appearance (in the dried specimen the surface is worm-eaten). Loss of bone substance except in the cortex is rare—*i. e.*, central gumma.

FIG. 519.—DRIED SPECIMEN OF OSTEOMYELITIS OF RADIUS, SHOWING LARGE SEQUESTRUM AND INVOLUCRUM. (Warren Museum.)

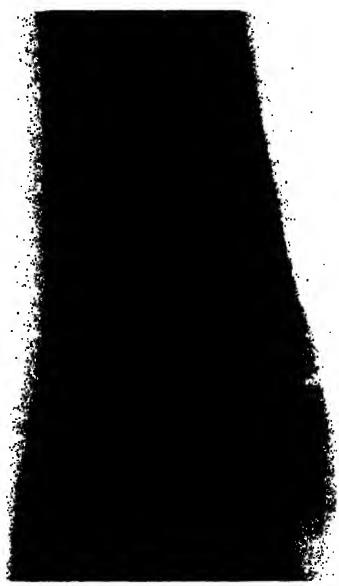

FIG. 520.—OSTEOMYELITIS IN SPONGY BONE AT LOWER END OF TIBIA, FORMING A LARGE "BONE-ABSCESS" WITH DENSE WALLS.

Osteomyelitis due to staphylococcus and other pus-producing organisms *affects diaphysis far more than epiphysis. In early stages does not affect inorganic constituents of the bone. Usually characterized by both increase and loss of bone substance. Sequestra large and clearly defined. Abscesses large and with dense walls in proportion to their age.*

During acute and painful stage there is no change in the inorganic bone, but when the infection has existed for a few weeks, there is solution of trabeculæ where the spongy bone is affected, and deposits of new bone where the periosteum is lifted by pus and where the line of demarcation exists in the spongy bone. Old eburnated sequestra are very dense and lie embedded in granulation tissue or pus, which have very little density, and separate them from the involucrum.

Sequestra are usually composed of the whole cortex or portions of the cortex, and preserve the same outline as the original shaft. They do not become dissolved

in the pus, as do the trabeculæ in the spongy portion of the bone. In some old cases they are even more dense than normal bone.

Bone-abscesses due to infection of the spongy tissue become larger (*e. g.*, larger than hazel-nut) than tuberculous abscesses and have little density in their centers and increased density in the wall of healthy bone which surrounds them. Such abscesses, when old, may be surrounded by a thick, dense, eburnated wall.

Old cases of septic osteitis sometimes present a bizarre appearance, due to solution of bone in some places and excessive deposit of lime salts in others. The

FIG. 521.—BONE-ABSCESS OF MANY YEARS' DURATION IN UPPER END OF TIBIA. Wall is so dense that cavity is barely shown

FIG. 522.—TYPHOID OSTEOMYELITIS OF TIBIA, SHOWING "BONE BLISTER."

joints are rarely involved. Adjacent parts of the bone are more often hypertrophic than atrophic.

Typhoid osteomyelitis is usually subperiosteal, causes a localized cortical hypertrophy and a "bone blister" resembling syphilis, but without as much general cortical thickening in the neighborhood.

Chronic Arthritis.—The clinical division of the forms of chronic arthritis which have been called gouty and rheumatic has never been satisfactory. It seems likely that the x-ray will help to bring about a more rational classification. From an x-ray point of view it is not difficult to divide these cases into three types which, to a certain extent, may also be distinguished clinically.

Hypertrophic, in which there is new bone formation in the form of rims and spurs at the articular edges and well-marked density in the bones.

Atrophic, in which the bones are below normal in density, and the articular cartilage is atrophied so that the normal joint space is obliterated.

These two types are occasionally mixed.

True gout, where tophi of little density occur and erosions of the sides of phalanges are present.

In the **non-suppurative joint infections** there is usually no change in the articular surfaces to be seen in the plate. In some cases, however, there is marked destruction of articular surfaces almost resembling tuberculosis.

FIG. 523.—HYPERTROPHIC ARTHRITIS OF THUMB.

FIG. 524.—ATROPHIC ARTHRITIS.

Bone Atrophy.—The use of the x-ray has made obvious the fact that bone, like other tissues, shrinks and dwindles from disease and disuse. The inorganic structure of the bones of an inactive old man differs almost as much as his muscular condition from that of a young man. The trabecular spacing is more widely meshed and more clearly marked. In the atrophy consequent on disease the reverse is the case, and the trabecular marking is less distinct. The penciled outlines of the bones adjacent to tuberculous disease has already been mentioned. Sudeck has called attention to an essential acute inflammatory bone atrophy. In this condition there is an absorption of lime salts. It is frequently seen in gonorrheal arthritis and in the bones adjacent to septic joints, and is probably the condition present in some cases of "infectious arthritis."

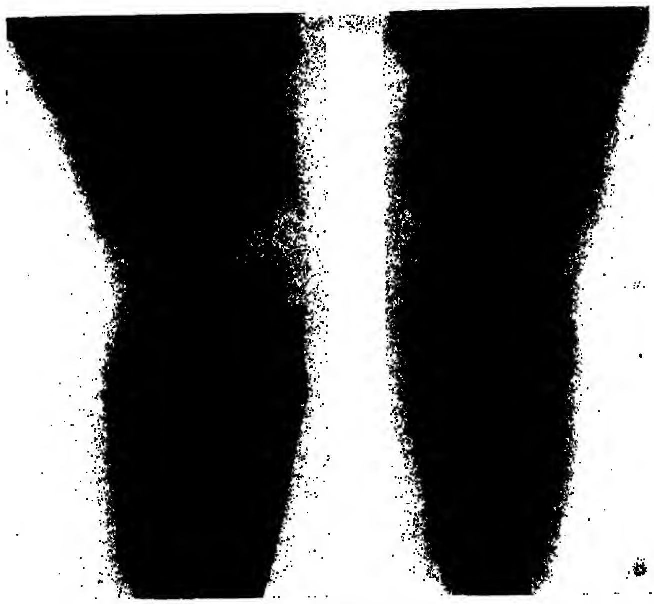

FIG. 525.—RACHITIC KNEES.

Rickets.—The long bones are bowed and the cortex on the concave side thickened. The epiphyseal ends of the diaphyses are broadened and frequently contain small irregular areas, filled with tissue of little density. The center of ossification of the epiphysis is small, and presents a smooth contour toward the joint and an irregular one toward the epiphyseal line. The epiphyseal cartilage itself is much thicker than normal, and its demarcation from the diaphysis very indefinite.

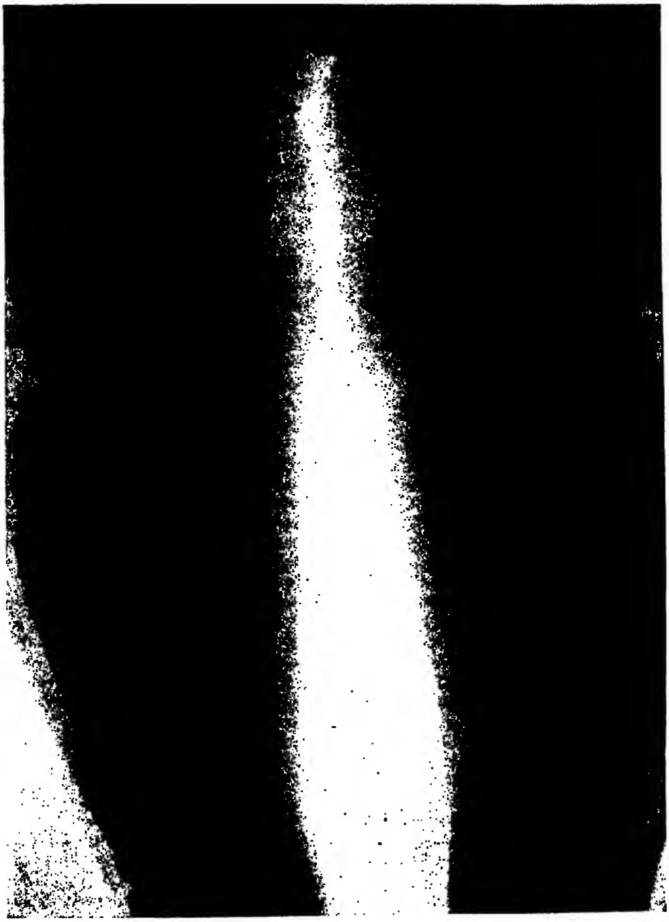

FIG. 526.—CHONDRODYSTROPHIA FŒTALIS.

Chondrodystrophia Fœtalis.—The bones of the limbs are shorter than normal, but straight (except in infants). The epiphyseal ends of the long bones are sharply broadened (see rickets, in which the broadening is gradual). The epiphyseal line is abnormally narrow and the structure of the adjacent bone is normal.

FIG. 527.—PERIOSTEAL DYSPLASIA. (Warren Museum.)

Periosteal Dysplasia.—The epiphyses are of normal size and shape, while in the shaft there is an absence or great diminution of cortical bone formation, so that bending and fracture are common.

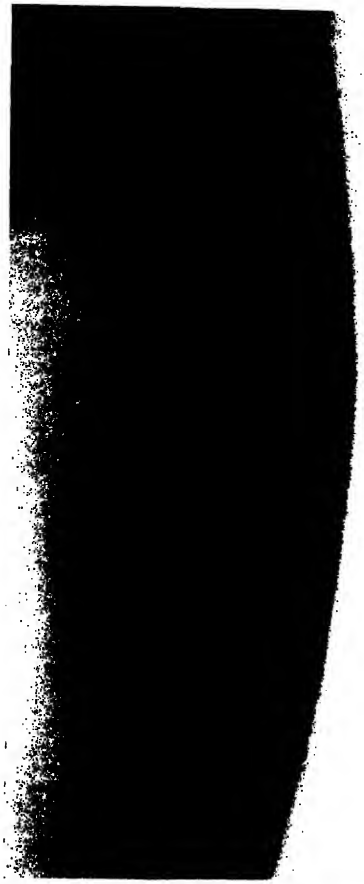

Fig. 528.—Osteitis Deformans of Femur.

Osteitis deformans usually affects the long bones, which are frequently bowed. Characterized by great increase of width of cortex, but for its size the bone has often less density than normal and may appear laminated in the x-ray picture.

Osteomalacia.—General and local loss of density, so that the medulla increases in width at the expense of the cortex. Cyst formation without dense wall. Sometimes sharp angulation; fractures common.

FIG. 529.—MULTIPLE CHONDRAL EXOSTOSES.

FIG. 530.—ISOLATED CHONDROMA OF METACARPAL.

Multiple Chondral Exostoses.—Commonest near the epiphyseal lines, but may occur on shaft. Usually contain lime salts, particularly next to their capsule. Bases of tumors may displace true bone at point of origin, so that cortex is indented with cartilage. Outlines of tumors irregular, but smooth. Disturbance of growth at epiphyseal lines may lead to asymmetric growth of bones (manu radioflexa). Since cartilage has little density, it does not show in the skiagraph except when there is ossification in it, or by contrast, where it has displaced normal bone. Most chondromata contain a framework or core of bone and have islands of bone in their substance.

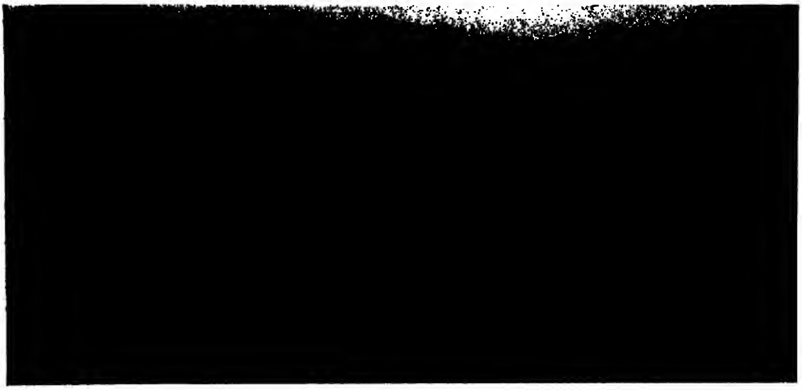

FIG. 531.—OSTEOMA OF FEMUR. (Exostosis bursata.)

Osteomata vary greatly in shape and density according to the clinical varieties of osteoma eburneum, spongiosum, etc. Their structure bears the same relation to the *x*-ray as ordinary bone.

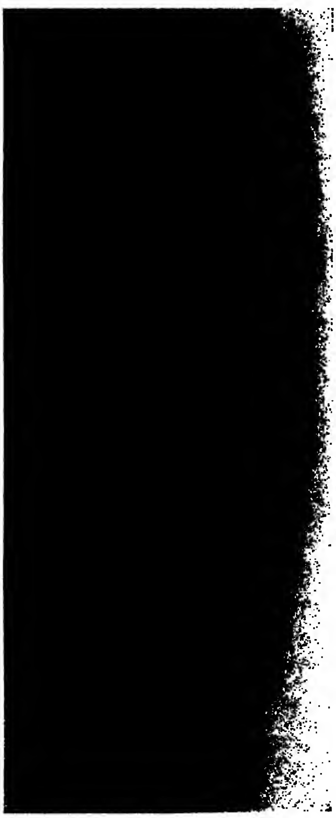

FIG. 532.—MEDULLARY SARCOMA OF HUMERUS.

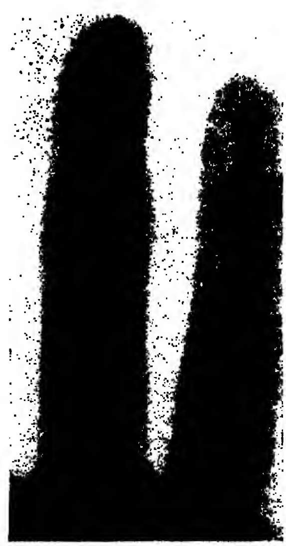

FIG. 533.—BONE-CYST OF FINGER.

Medullary giant-cell sarcoma originates in the spongy tissues or medulla, and in its growth destroys the cortex from within outward. Encapsulated in a

thin shell of dense new bone. Fine trabeculæ may pass through its substance from wall to wall of the capsule. Adjacent bone beyond capsule normal. Myeloma, metastatic hypernephroma, and carcinoma and simple bone-cyst affect the inorganic bone in much the same way and, therefore, may present similar appearances in the x-ray picture.

Sarcoma of Bone Other than Medullary.—Remnants of the old shaft may be found in the center of the tumor. In some forms, *e. g.*, in periosteal or ossifying sarcoma, the bone is stimulated to grow and there is a deposit of new spicules which radiate from the cortex into the tumor. In these cases the old shaft preserves its normal contour.[1] In other forms, *e. g.*, in certain round-cell types, there is no new

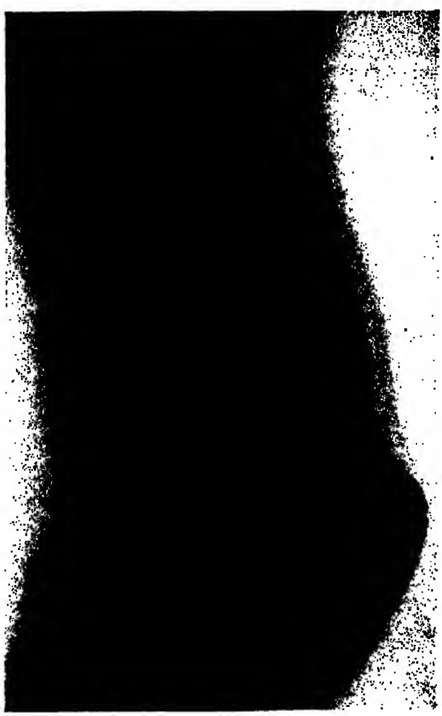

FIG. 534.—PERIOSTEAL SARCOMA OF LOWER END OF FEMUR.

formation of lime salts, but the old cortex is gradually dissolved. In these cases the x-ray shows that the density of the shaft is diminished or there are islands of old bone remaining in the tumor.

The following example is arranged to show the proper logical use of the x-ray in diagnosis:

Clinical Case.—A girl of twelve years is lame and complaining of pain, but is unable to give a clear history. Examination shows that the left lower leg is swollen and tender. Clinically, it is impossible to tell whether there is a fracture present,

[1] In many cases near the junction of the healthy bone with the tumor there is reactive new bone formation beneath the periosteum. At the edge of the tumor this layer of new bone ends abruptly and gives a characteristic appearance in the skiagraph.

whether the bone is affected at all or only the soft parts, or whether we are dealing with syphilis, tuberculosis, rickets, osteomyelitis, or new-growth of the bone; *x*-rays are taken and show no indications of fracture, but they do show that the bone is affected in the following manner:

	x-Ray Findings;		*We may Eliminate—*
e. g.	A focus the size of a pea, in which the trabecular marking sare indistinct and the walls of which are ill defined, exists in the epiphysis of the tibia. The adjacent soft parts are thickened and the bones of the foot show marked atrophy and penciled outlines.	*Syph.*	Because the epiphysis is affected instead of the diaphysis, etc. No cortical thickening or bone blister, etc. Focus is small and wall is not dense, etc. Epiphyseal end of diaphysis not broadened or epiphyseal zone wide, etc. Inflammatory thickening in soft parts and atrophy of other bones, etc. Tuberculosis—entirely consistent appearances.
or *e. g.*	Fibula, joint, and epiphysis of tibia normal. Great thickening of shaft of tibia. A portion of the old cortex, somewhat more dense than the rest and several inches long, is surrounded by a zone of less dense tissue, and outside of this new-formed cortical bone—sequestrum.	*Ty. O.*	Because of the presence of a sequestrum, etc. Because it is usually only subperiosteal. No "bone blister," etc. Septic osteomyelitis — entirely consistent appearances. Epiphyseal end of diaphysis and epiphyseal zone normal, etc. They do not cause sequestra, etc. Sequestrum is in cortex, is too large and well defined, etc.
or *e. g.*	The cortex of the shaft of the tibia is thickened. A bone blister is present on anterior surface. There is increase of cortical bone on a limited area of fibula. Joint surfaces and epiphyses are normal.	*Sep. O.*	Syphilis—entirely consistent appearances. Not inconsistent, but too extensive, etc. No sequestra or abscess and presence of bone blister, etc. Epiphyseal zone normal, etc. No new-growth is known to cause similar appearance, etc. Epiphyses normal and shaft affected, etc.

DELETERIOUS EFFECTS OF THE *X*-RAY.

During the early months of the use of the *x*-ray it was supposed that it traversed living tissue without causing any effect whatever either for good or ill. In the spring of 1896, however, reports appeared in the medical journals of cases in which a dermatitis resembling a burn followed within a few days or weeks after *x*-ray exposures. In some cases these 'burns'' were so severe as to amount to a malignant ulceration with little tendency to heal. During 1896, 55 such cases of all grades of severity were reported; 12 more were reported in 1897; 6 in 1898, and occasional cases since. Fortunately, the medical press published and republished these early cases again and again. One journal copied the description from another, so that although the number of burns which had occurred was greatly exaggerated, never-

theless they served to spread the warning, and such cases in a few years became very rare.

In 1902 I collected all the cases which had been reported up to that time and only succeeded in finding about 200. From a calculation of the probable number of exposures made during that time it was evident that not one case in 10,000 suffered injury. With modern methods the danger to the patient is far less than this in diagnostic exposures, since they are made more rapidly and with the tube at a greater distance from the skin.

The following extracts are from my article published in 1902:

"The injurious effects of the x-ray fall naturally in five classes: (*a*) **Skiagrapher's dermatitis** occurs chiefly on the hands or faces of x-ray workers—in those who are frequently exposed to the action of the rays, in tube-makers, experimenters, exhibitors, and professional

FIG. 535.—RESULT OF CHRONIC x-RAY DERMATITIS.
Hand showing extreme degree of skiagrapher's dermatitis which has led to loss of nails, keratoses, and epitheliomata, requiring amputation of fingers.

skiagraphers. It results from repeated short exposures, usually in the use of the fluoroscope or from demonstration of the bones of the hands to an audience. It is most often of a mild degree, but with continued exposure may go on to ulceration and gangrene of the skin, even to involvement of the tendon sheaths and joints. In the less pronounced forms the skin appears chapped and roughened and the normal markings are destroyed; at the knuckles the folds of skin are swollen and stiff, while between there is a peculiar dotting resembling small capillary hemorrhages. The nutrition of the nails is affected, so that the longitudinal striation becomes marked and the substance becomes brittle. If the process is more severe there is a formation of blebs, exfoliation of epidermis, and loss of the nails. In the worst form the skin is entirely destroyed in places, the nails do not reappear, and the tendons and joints are damaged."

(Since this description was written a number of well authenticated

RESULT OF CHRONIC x-RAY DERMATITIS.

haracteristic striation of finger-nails and mottling of skin. A portion of
f the ring finger was protected by a ring and, therefore, does not show a
e. The other light areas over the knuckles are the results of skin grafts
from which keratoses have been removed. On the index, ring, and lit

cases have been published, showing that epithelioma may spontaneously develop in these ulcerations and in several cases have required amputation. There have also been a few cases reported in which the eyes have been injured, but such cases are extremely rare.)

"The next three classes of cases occur accidentally in patients who are exposed one or several times at short intervals for skiagraphs. They vary in intensity and may be directly compared with burns of the first, second, and third degree. They are essentially the same as the forms occurring in skiagraphers spoken of above.

"(*b*) The mild cases are simply a transient erythema lasting perhaps a few days, followed by an exfoliation of superficial epidermis. There may be hyperesthesia of the skin and a slight burning sensation, but no real pain. In the hairy portions depilation may occur without inflammatory signs.

"(*c*) In cases of the second degree there is a formation of blisters following the erythema; these may be serous or purulent; the condition resembles a scald, but is slower in healing and less acute in character.

"(*d*) In the worst cases the process, instead of disappearing in a few weeks, seems to extend to the deeper layers of the skin and subcutaneous tissues. There is a formation of leathery slough, surrounded by a brawny, indurated swelling with ill-defined limits. The process is exceedingly slow and obstinate and possesses an almost malignant tendency to progress. It is very painful at times and resists treatment in a remarkable way. The reader is referred to the case of Cassidy and to the report of Orleman, which are typical cases of this kind.

"(*e*) The fifth group of cases is composed of those in which some internal lesion is attributed to the x-ray. There have been few such cases recorded, and these have been in such an inexact and hypothetic way, with the exception of that of Gilchrist, that they seem to the writer to be undeserving of record."

In the light of more recent observations the last clause of this extract needs modification. Recently evidence has come out which tends to show that the x-ray may have insidious, injurious effects on the internal organs as well as on the skin. Dr. F. Tilden Brown has called attention to the frequency of azoöspermia in x-ray workers, and Frieben and Bergonie have shown that by repeated x-ray exposures it is possible to cause a suspension of function and ultimately partial atrophy of the testicles or ovaries of guinea-pigs and rats. It is not unlikely, as pointed out by Edsall, that other organs may be affected, especially the bone-marrow and the kidneys. The experiments of Rollins, Allen, Warthin, Heineke, and others tend to show that the x-ray may have a very powerful and at times selective action on the different tissues of the body. This is evidently of especial importance in certain diseases, for skiagraphers in all parts of the world have reported the occurrence of toxemic symptoms in patients exposed to the x-ray for the treatment of Hodgkin's disease.

On the other hand, in healthy patients, or even in patients with serious constitutional disease, symptoms following x-ray exposures for

diagnostic purposes have been so seldom noted among the millions of exposures that have been made, that it would be folly to argue that a mere diagnostic exposure of a few minutes is dangerous. The reports have been so few that for the present they may be regarded as mere coincidences. Even in the experiments by which such deleterious effects in animals have been produced, the exposures have had to be long and at close range. Nevertheless, as pointed out by Edsall, it is well to have due regard to the possibility of such results, especially in cases in which the function of the bone-marrow, spleen, lymphatic glands, or kidneys is already abnormal.

Försterling has shown that even a single exposure of moderate strength (ten minutes at 20 cm.) produces a pronounced inhibition to development in growing puppies—*e. g.*, the growth of one leg could be stunted. His experiments indicate that especial caution should be used in exposing children to the x-ray even for diagnosis.

There is little doubt of the frequency of sterility and azoöspermia in skiagraphers, yet it must require a considerable amount of exposure to bring about this result, for in a number of instances personally known to the writer living spermatozoa can be demonstrated in the seminal fluid of individuals who some years ago worked a great deal and unprotected in the presence of strong radiation. In one of these cases there had been an x-ray dermatitis about the outer side of one thigh. In two other cases physicians who had used the x-ray to a considerable extent have since become fathers of healthy children.

While it is true that nowadays danger to the patient in diagnostic exposures is scarcely to be feared, the danger to the patient undergoing therapeutic treatment by the x-ray is still very great and the danger to the skiagrapher is greatest of all. Aside from the risk of depilation, conjunctivitis, dermatitis, loss of finger-nails and phalanges, sterility, epidermoid cancer, and nephritis, there can be little doubt that the general health and well being may become affected in time unless the greatest precautions are taken. As a rule, eager, enthusiastic young men who in their devotion to their work are careless of their personal danger from so insidious an enemy, take up this occupation. None should undertake it without due consideration of its risks.

The responsibility for selecting persons to do x-ray work and for the use of proper precautions in its practical application rests with the executive officers and trustees of hospitals, which nowadays set the example for the community in such matters.

The details for the construction of appliance to give adequate protection to the patient and skiagrapher would be out of place here, but this general principle might be insisted upon. While his apparatus is in action, the skiagrapher should stand in such a position in relation to it that the rays are entirely excluded, as demonstrated by a photographic plate exposed for ten minutes' time. It is not difficult to arrange, with the aid of sheet lead, lead-glass plates, and mirrors, a screen which will thus protect the operator and still allow him to observe the action of his tube. The use of the fluoroscope should be

abandoned, except in cases of great importance or when protected with the greatest care.

The protection of the patient is more difficult, though not so necessary, since the exposures are so short. A protection of the parts of the body not necessarily exposed by a screen equivalent to a $\frac{1}{32}$-inch of sheet lead may be considered a practical amount of precaution.

BENEFICIAL EFFECTS OF THE RÖNTGEN RAY.

Not long after it was observed that the Röntgen ray had a harmful effect on the tissues, the possibility of its having a beneficial effect naturally suggested itself, and its action on all forms of disease was tried. Such a mass of literature has accumulated on this branch of its application that it would be difficult to eview it in a large volume, but all writers agree that it is of more or less value in the treatment of certain conditions. At present the therapeutic use of the x-ray is rightly falling into the hands of the dermatologist and the medical clinician. To dermatology especially it has been a great boon in the treatment of obstinate diseases of the skin, such as psoriasis, chronic eczema, and sycosis. The internist finds it a help in certain cases of leukemia, but, owing to the obvious difficulty in using such a powerful remedy, is proceeding with caution.

There are few diseases in which enough has yet been accomplished to interest the surgeon. In lupus, epithelioma, keloid, carcinoma and sarcoma, both before and after operation, exophthalmic goiter, tuberculous adenitis, and Hodgkin's disease its results have been somewhat encouraging.

Lupus and **scrofuloderma** may unquestionably be sometimes cured, but the improvement is uncertain and slow—a matter of months or years—and, therefore, necessitates tedious and expensive treatment. The dermatitis resulting from long treatment is likely to leave as conspicuous a condition of the skin as a surgical scar. Obviously, in some cases where excision is impracticable the x-ray may be of great help.

Keloid may or may not yield to the x-ray. A few exposures will usually show improvement if any may be expected. If prolonged use of the x-ray is necessary, surgical treatment is preferable.

Superficial epithelioma and **rodent ulcer** may be cured by the x-ray in many cases, but where the subcutaneous tissue or fascia is involved, cure is very rare, although superficial healing may take place. In treating these diseases both surgery and the x-ray are undertaken too lightly. The desire of the dermatologist or practitioner to avoid ugly scar formation leads him too often to recommend caustics, curettage, radium, the x-ray, or an inadequate excision. It is not infrequent nowadays to find patients with these lesions who have had both repeated operations and repeated x-ray treatments. It is altogether too common in hospital work to find epithelioma being treated by assistants in out-patient departments or inexperienced surgeons who remove the growth with too narrow a margin. While Röntgen therapy

compares favorably with the results of such inadequate excision, a proper plastic radical operation in competent hands is preferable in most instances. In inoperable cases, in cases which are not susceptible to plastic repair, in the timorous, in the aged, and in the feeble the x-ray has an undoubted field of usefulness; in ordinary cases excision with a wide margin is surer, quicker, and less expensive.

Epitheliomata of the mucous membranes are less susceptible to the x-ray than those of the skin, and it is unjustifiable to waste time with its use if operation can be considered. It is not unlikely that the x-ray even stimulates some of these cases to grow more rapidly.

In spite of the thousands of attempts which must have been made to cause the disappearance of **carcinoma and sarcoma primary in the deeper parts** of the body, so few successful cases have been reported that operation, where possible, must still be preferred. In inoperable cases the x-ray may be used with a little real hope, for a number of authentic cures have been reported. I have seen a large sarcoma of the clavicular region practically disappear under x-ray treatment, although it reappeared again some months later. Similar cases have been reported by others, as Coley, Pusey, and Beck. Such results have been too few, however, to show clearly that they are not cases of spontaneous disappearance or erroneous diagnosis.

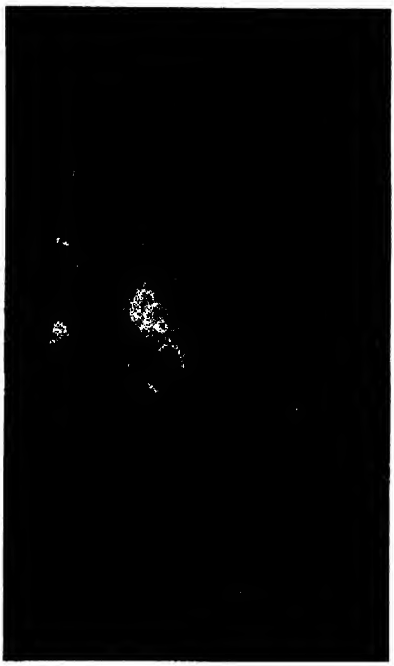

Fig. 536.—Epitheliomata before Treatment. (W. A. Pusey.)

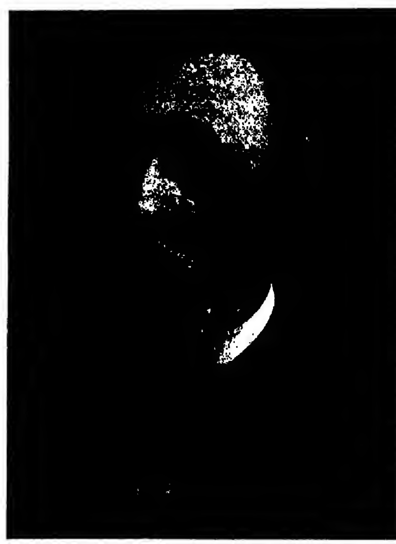

Fig. 537.—Same case as Fig. 536, after treatment. (W. A. Pusey.)

The x-ray sometimes affords a temporary relief in **post-operative recurrent cancer.** All experienced skiagraphers have observed the disappearance of nodules of recurrent cancer in and about scars. There is some, but not sufficient, evidence to show that metastases in lymphatic

glands may disappear under its use. It is probable that in many instances such shrinkage in the glands is due to the subsiding of inflammatory conditions. I have observed the steady enlargement of metastases in the lymphatic glands to be coincident with the disappearance of a large superficial recurrent cancer in the same subject, while both lesions were under treatment.

It is meddlesome to advise pre-operative *x*-ray exposure, and my experience makes me disinclined to advise post-operative treatment for the sake of mere prophylaxis. In two cases in which such an effort was consistently and conscientiously made, no good was obtained. Where the surgeon is conscious that he has not removed the whole growth and fears immediate recurrence, it is rational to advise post-operative exposures, but where there is a reasonable hope that the disease has been eradicated, part of the benefit of the operation is lost by nagging the patient by a treatment from which no great good can be expected and which only reminds him of his danger.

In **exophthalmic goiter** the use of the *x*-ray has been encouraging, but, owing to the fluctuating character of this disease, the reports of success in any form of treatment must be especially favorable to be convincing. Reports of its use in **Hodgkin's disease** have been so uniform that it may be stated with a fair degree of certainty that the glandular enlargements may be made to shrink and even disappear, but that during this process such a toxemia becomes evident that the fatal termination of the case may be hastened.

In **simple** or **tuberculous adenitis** a decidedly favorable action has been reported, but this result is not always obtained and the treatment must be so long continued in most cases that the danger of ill effects counterbalances the good obtained.

In spite of the fact that as yet it must be confessed that the *x*-ray has not proved a great success as a therapeutic agent, one must admit that it is a powerful agent, and that, as the knowledge of its administration increases, we may look for it to take a more definite place in the treatment of disease.

MISCELLANEOUS USES.

In the limited space in this volume devoted to the *x*-ray it has seemed best to speak mainly of the proved and acknowledged uses of this remarkable form of energy. Nevertheless, surgical science also profits by its help in many important contributions to other kindred branches of medical science. For instance, it has aided the advance of surgical anatomy, since the condition of the bones can now be studied more easily in the living than formerly in the dead. Such an important contribution as Böhm's explanation of lateral curvature has been directly a consequence of the use of the *x*-ray. In physiology it has made it possible for Cannon to describe the hitherto unexplained movements of the stomach and intestines. His method of using emulsions of bismuth has already been utilized by Rieder in determining the location of strictures of the esophagus, stomach, and intestine in man.

By the same procedure diverticula in the bladder (Wolff) and labyrinthine sinuses about diseased joints (Lovett) may be graphically shown.

On the border line between medicine and surgery it is of great assistance in the diagnosis of aneurysm, mediastinal tumors, abscesses in the lung and below the diaphragm. In pathology it is helping to clear up the confusion of classification in the various forms of arthritis, of osteomalacia, and of sarcomata of the bone.

RADIUM.

Since the discovery that Röntgen rays could be produced by laboratory methods it has been found that certain mineral substances possess the property of emitting rays similar to, if not identical with, the *x*-rays. The most powerful of these substances are uranium, thorium, polonium, radium, and their salts. These substances are most interesting from a physical point of view, but as yet are not of much importance to the surgeon. Radium alone seems to have sufficient power to make it of value for therapeutic purposes. At present its price, if pure enough to be of value, prohibits its general use, although experiments have already been undertaken with it to a certain extent. Abbe and others report that its effects on living tissues, whether normal or pathologic, are similar to those of the *x*-ray. It is not clear that it is superior to the *x*-ray, except that it is far more convenient to use and that it is possible to administer it much more accurately as regards dosage. It is relatively useless for skiagraphic work.

Owing to the disappointments occasioned by the use of impure and weak radium salts which have been put on the market, the use of radium probably has not even received the credit that it deserves from conservative members of the profession. It is to be hoped that those who have undertaken to find the way with radium will make certain of their path before urging the rest of the profession to follow.

LATEST RESEARCHES.

Lately there has been established in Paris an Institute of Radio-Activity which is fortunate enough to have associated with it Madame Curie, the discoverer of radium, and a number of active medical men who are investigating the possibilities of radio-activity in the treatment of disease. The result of their investigations, especially in the treatment of cancer, have been sufficiently encouraging to warrent the establishment of a Radium Institute in London under the patronage of the King. Connected with it are such well-known men as Sir Lauder Brunton, Sir Frederick Treves, and others.

Those who desire further information about both these Institutions will find it, perhaps, best stated in English up to date (September, 1909) by referring to the British Medical Journal, vol. i., 1909, pp. 242, 301, 356, 437, 609, 614, 797, 912 (2 papers), 1131, 1250, 1557, the very interesting Croonian lectures of Lazarus-Barlow, in the same journal for June 19 and 26, 1909, and the important paper by Wickham in its issue for August 21, 1909.

At present, in cases of malignant disease, it would be very premature to rely upon radium rather than upon complete surgical operation, but it is not improbable that within the next few years the exact status of this wonderful therapeutic agent will be given to the world by eminent scientific authority.

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CHAPTER LXXXIV.

THE LEGAL RELATIONS OF THE SURGEON.

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THE SURGEON AS A WITNESS.

As Ordinary Witness.—The primary meaning of the word "witness" is "one who sees or knows personally."[1] The surgeon may at any time be summoned, under subpœna, as an *ordinary* witness, for the *ordinary fees*, to speak of facts actually within his own personal knowledge and observation, based on his own senses; he must not tell what others have seen or heard or told him.

His Attendance in Court is Compulsory.—If acquainted with a case through attendance or observation, professional or casual, he may be required, in civil or criminal proceedings, to tell what he has seen or heard, *subject only to the privileges hereinafter mentioned.* He is not bound to attend, to operate, or to consult, but if he does so, or if he be but an accidental witness, he cannot withhold his knowledge of the facts when *under subpœna* in a judicial investigation.[2] Disobedience may mean attachment for contempt of court and the imposition of a fine.

Original Notes.—The predicament of a witness depends upon the chances of life. The first hour of his practice or his busiest employments may hear the call. Hence, he should be prepared to testify fully and accurately. *As to facts:* he should be clear as to dates, times, distances, size, measurement of objects, direction, depth and character of wounds, fractures, etc. He should not confuse facts and opinions. His statement should be methodical, chronological, and complete in detail, based upon an orderly and methodical inspection and examination. Virchow dwells upon and prescribes an order.[3] *He should cultivate the faculty of minute detailed observation, and form the habit of making accurate and full notes at the time, or at the earliest moment afterward, so as not to suffer from indistinctness of memory. These notes, no matter how rough, should be preserved as originally made, unchanged and without later additions.* Full, or even scrappy, memoranda made at the time, or so soon thereafter as is practicable, are of real value. Their function is to refresh the memory,[4] even if made by an assistant, under the conditions stated. If the witness, though believing in their accuracy, cannot recall what they refer to, or has no recollection outside of them, they cannot be received or read aloud as a substitute for testimony.

Notes should be accurate in day, hour, place, circumstances; surrounding conditions, disturbed or otherwise; the absence or presence of persons; the results of inspection, both external and internal; corporal effects and symptoms; the absence of usual symptoms; the presence of the abnormal; measurements of wounds, depth, direction, and character; the signs of hemorrhage; the indications of violence, self-imposed or otherwise; the relations of weapons to a body, proximity, caliber, or direction; signs of the operation of a drug, poison, or disease; the character, size, and appearance of fractures, and all means resorted to in their reduction, adjustment, and treatment, and their results, with particularity. If the scene be one of possible crime, a rough sketch may be added. *Destruction* or loss of original notes casts suspicion upon testimony and upon "copies," which may have been added to or "written up." Neatness is no substitute for authenticity.

The accurate observations of Sir Astley Cooper, as noted, led to the conviction of a *left*-handed murderer; and Koch's analytic and orderly testimony in the Speichert poisoning case convicted the prisoner.

Dying Declarations (Ante-mortem Statements).—Surgeons, as well as laymen, may be called to testify to what they heard a dying man declare:[5] (*a*) Death must actually ensue and be that of the declarant. (*b*) There must be consciousness of the certainty of death and no hope of recovery on the part of the patient. (*c*) The actual period of survival after the declaration is immaterial. The expectation of death at the time of the declaration, the pressure of impending doom, gives the declaration its solemnity. (*d*) The declaration should be noted in the exact words of the declarant; do not paraphrase; *if circumstances permit*, write out the declaration; have it signed by declarant or attested by witnesses present. Call in a notary or a magistrate to swear declarant. If impossible, reduce the declaration to writing at the earliest practicable moment.

Manner of Testifying.—Conduct yourself with patience, dignity, courage, and self-possession. With the consequences of testimony you have nothing to do: that is for the judge and jury. State facts exactly as you saw or found them. Discard opinions, hearsay, and conjectures. Repress partisanship or sympathy. Give strict attention to the questions put, answer responsively, and within the limits of the question. Beware of double-barreled questions. If unintelligible, or containing confusing elements, risk no answer which may be misunderstood or misapplied. Either state an inability to answer the question as put, or, if forced to a precise answer in form, add the necessary qualification or explanation. Avoid argument or disputation; be plain of speech; avoid technical terms, or, if their use be necessary, translate them into intelligible terms. Do not call a "blood clot" "an apoplectic extravasation." Neither judges nor jurors are medical men. Be simple, straightforward, and direct. Keep your temper under galling fire. If objection be made by counsel, never answer until the court has overruled the objection. The *cross-examination* will involve tests of observation, memory, and bias.

Privileged Communications.—For centuries surgeons had no privileges as to disclosures made to them by their patients, or as to facts learned by them while in attendance, or as to symptoms or scars of a secret nature observed by them. At present, in New York, a statute forbids the disclosure by the surgeon of "any information which he has acquired *in attending a patient in a professional capacity*, and which was necessary to enable him to act in that capacity." In Pennsylvania "no person authorized to practice physic or surgery shall be allowed, *in any civil case*, to disclose information which he acquired in attending a patient in a professional capacity, and which was necessary to enable him to act in that capacity, and which shall tend to blacken the character of the patient, without his consent." Most of the States have statutes similar in substance, but varying in phraseology. In other States, notably in Massachusetts, the common law rule prevails that communications from patients *are not privileged.*[6] As distinctions exist between civil and criminal proceedings; as murder, abortion, and other crimes involve public interests; as the relation of patient and surgeon may be open to legal construction; as the character of the knowledge and the manner of its acquisition may be open to dispute; and, further, as the cases may vary as to whether they affect character, contracts, matrimonial engagements, insurance, or accident law, insanity, testamentary capacity, or malpractice, it would be unsafe to attempt the statement of a general rule as to the extent of privilege. The safest course *in all cases, in all jurisdictions*, is for the surgeon, *when checked by his ethical sense*, before answering any question touching privilege, to appeal to the court to decide whether the question shall be answered. Counsel will be quick to argue. If the judge rules that it must be answered, the responsibility for the disclosure is upon him.[7]

Four points must be borne in mind: (*a*) In no State does the privilege protect consultations for the purpose of committing an act forbidden by law. Infanticide, abortion, abandonment of infants, baby-farming, conspiracies to commit crime or to defame, attempts at suicide or invitations to euthanasia, and other crimes, are all outside the pale.[8] (*b*) Confessions of past crimes, conditions existing subsequent to criminal acts, and the fact of the possession of suitable instruments for the commission of crime are not privileged. (*c*) In no jurisdiction does the privilege belong to the surgeon. *It is the privilege of the patient*, and may be waived by him. If waived, the surgeon may and must testify fully. What amounts to a waiver, express or implied, is a question for the court. (*d*) The admissibility of any evidence or of any question or answer is always for the court.

As Expert Witness.—The secondary meaning of the word "witness" is "one who gives testimony or evidence." From necessity, in matters beyond common knowledge, an *opinion* may be requested of one, fitted by special experience and by scientific training, to aid a court and jury in reaching a result, based on his general knowledge and experience, or upon the significance of facts testified to by others, *the truth of which he is asked to assume.* The basis of the opinion must be

found in the *hypothetical question.* Where personal observation is had, hypothetical presentation is unnecessary; where personal observation is lacking, hypothetical presentation must be resorted to for the premises to support the conclusion. *Only skilled witnesses* may be asked hypothetical questions. As the witness is invited to draw a conclusion, the premises must be considered. If the premises fail, the conclusion must be disregarded. If the premises are insufficient, the conclusion should not be hazarded. Be careful that the hypothetical question states *all* the facts necessary to support the opinion. Do not let the answer topple for want of support. Give the closest attention to the facts which you are asked to assume as true before stating a conclusion. Here the province of the expert ends. With the effect upon the case, or with the final result, he has nothing to do. If the verdict is adverse to the side which calls him, he should feel no chagrin, for if the facts assumed are not found by the jury, the conclusion necessarily falls. This is no impeachment of the expert, who is not responsible for the facts, nor should he usurp the functions of the jury or make himself a partisan. The form and scope of the question and the data assumed under the evidence already presented must be passed on by the court. *The important point to be observed by the expert is whether the premises as stated are sufficient to justify his conclusion.* The cross-examination will soon put him to the test. Never hazard an opinion without preparation. Read the authorities. Be familiar with the opinions held and expressed by them and the grounds on which they rest. If your own experience leads you to different results, say so, but do not ridicule authority. *Remember that the authorities will be thrust at you on cross-examination.*

The Skill Required of an Expert.—Experts are the severest critics of each other, and they chafe under the willingness of the courts to hear men of moderate rank. *The expert is not called on to decide the point at issue,* nor to give an opinion as to the merits of the case; he is called to aid a legal tribunal. Where there are so many grades of knowledge, the only safe rule is to ascertain the extent of the witness' qualifications and within their range to permit him to speak.[9] Cross-examination and the corrective testimony of others will test his value. *Specialists* are in most communities few and far between. It is only in large cities that they are readily had. Hence the ordinary practitioner is received in all matters as to which a regular surgical training necessarily involves some general knowledge. Whether the witness is sufficiently qualified is for the discretion of the judge, and before permitting an expert to testify, he may examine him or hear evidence to satisfy himself that he is what he assumes to be. A decision that a professional nurse who had nursed in 20 or 30 cases of bone felon, but who was not a student of surgery, was not competent to speak as to whether a felon was cut to the bone, has been criticized severely as unwise interference with the discretion of a trial court.[10]

An expert may be qualified—(*a*) by *special* and *peculiar experience, i. e.,* more than common experience in the matter; (*b*) by *practical experience* obtained casually, but steadily and adequately in the course

of practice; (*c*) by scientific training directed to the acquisition of a knowledge of a branch of science; (*d*) while claiming superior and special knowledge, he is not presumed to know everything; but he ought to be fully acquainted with the latest and most exact knowledge of the scientific matters of which he testifies.[11]

Demeanor of Expert.—Attend to the premises; think deliberately; reach conclusions cautiously; state opinions honestly; avoid dogmatism; avoid partisanship; do not sit at the elbow of counsel to suggest the line of cross-examination of an expert on the other side. A surgical coach should not take the witness-stand, or, if he has been on the stand as a witness, he should not remain to defend himself. Much of the discredit attaching to the well-known "war of experts" is due to this practice. When surgeons become the active allies of counsel, their credit with the jury is seriously if not wholly impaired.

Cross-examination of Expert.—The expert will be asked to analyze his conclusions; to restate his premises; to admit that if the premises vary the conclusion will be different; and he will be asked, upon the assumption of a different state of facts (usually, though not necessarily, those contended for by the cross-examiner as being the true facts made by the evidence or about to be presented in evidence), to state a conclusion inconsistent with the views expressed in chief.

Books.—The expert's conclusions may be based in part on books which he has studied, but it is established that he cannot quote opinions from professional books, however standard the authority, in support of his own view, the reason being that the authors did not write under oath, and their grounds of belief and processes of reasoning cannot be tested by cross-examination.[12] Besides, the application of the text to the case in hand may be disputable. *On cross-examination*, an expert may be asked if he recognizes a certain author as a standard, and a quotation may be called to his attention which appears to contradict him. As a precaution, ask to see the book, to insure accuracy of quotation and the limitations of the context. Law cases differ as strangely as surgical cases, and the use of books must be left to the discretion of the trial judge. A charlatan is sometimes trapped by avowing knowledge of the works of a fictitious author.

Fees of Experts.—The term "fee" has been much misunderstood. *It does not mean adequate* compensation for service rendered, but the statutory *per diem* allowance payable to *all* witnesses, such an item of "costs" as may be taxed against the losing party. After much argument the stronger opinion, *based upon the weight of legal authority*, is that *in the absence of a statute allowing additional compensation to experts an expert is not entitled to demand additional compensation*, other than the ordinary witness fees, before giving testimony upon the stand.[13] The reader cannot safely rely upon the text of many writers. The equity seems strong in favor of the surgeon, but the common law makes no distinction as to witnesses. Every man, no matter what his calling, owes a duty to the administration of justice. A statute alone can change this, and but few States have statutes on this point, and these

are inadequate. Time is as important and knowledge as valuable to the laborer, the banker, the lawyer, the manufacturer, the actuary, the boiler-maker, or the engineer, if called as an expert, and none of these are favored.[14]

Dealing with the law as it is, *the surgeon called as an expert must obey the subpœna* and answer the questions put to him. *He is not obliged, however, to examine the case or reflect upon it, or to give more than an offhand opinion; nor can he be required to attend the trial so as to qualify himself, by listening to the testimony, to give a deliberate opinion as an expert; nor can he be required to make any examination or preliminary preparation.*[15] He can state his position to the judge.

The *practical result* is more satisfactory than any change in the law could make it. As parties to a cause, if wise, intrust to counsel the adequate preparation of a case, no prudent counsel will subpœna reluctant or unprepared witnesses as experts. There is entire freedom then for the expert *to arrange by contract in advance for his compensation.* This is not a "fee." It is a contract, and can be sued upon, if reasonable in amount and free from the taint of contingency upon the result of the suit in which the surgeon was called as a witness. If the agreement be for an indefinite amount and suit be brought, the recovery will depend upon what a jury may consider reasonable under the circumstances.

Sometimes the surgeon called as an ordinary witness may be questioned as an expert. He can protect himself by declining to answer in that capacity, on the ground that he is not prepared to express such an opinion, or he may appeal to the court on the ground that he has not been summoned as an expert, and that he prefers not to answer until he has been properly protected by a contract with the party calling him. The law will differ in various States. *The prudent course would be in all cases to consult counsel in advance as to the attitude to be taken.*

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MALPRACTICE.

A suit for malpractice is dreaded by the surgeon. It means bad practice, either of commission or omission; unskilful treatment, resulting in permanent or temporary injury to the patient; practice contrary to established rules, either of method or precaution; recklessness, carelessness.[1]

Negligence.—The legal responsibilities of surgeons are determined by a law applicable to every skilled profession: *every man must exercise diligence and care in the practice of his craft. He must have knowledge fit for the occasion, and must bring that knowledge to bear upon the case in his hands. Not only must he be possessed of skill, but he must exert it.* An ignoramus attempting an operation beyond his skill, and the most learned and skilful operator failing to exercise his knowledge, skill, judgment, and care, are alike negligent. A bungler, using improper instruments or those which he cannot handle, or accepting an assistant whom he ought to reject; the operator who selects or accepts an unskilled anesthetist, or the operator who, with knowledge of his own lack of skill, administers an anesthetic; a brilliant but hasty operator cutting off the wrong finger; the man with unclean hands, or who fails to guard against contagion; the intoxicated man; the man who accepts unsterilized instruments; who laughs at approved methods and recklessly experiments; the man who considers convenience and opportunity as equivalent to emergency and danger; who assumes consent to a major operation, or who transcends the limits of express authority; who fails to discover what could have been discovered as to conditions; who violates the rules as to extension and counter-extension; who omits to instruct nurse and patient as to their conduct and care; who abandons a case without notice or suitable provision for a substitute; the man who makes no notes or imperfect notes, but trusts to memory; in short, the man who is careless, reckless, or unskilful; these are the men who invite verdicts for damages.

On the other hand, the earnest, diligent, well-read, scientific surgeon, who has a library and reads his journals, who uses instruments of precision, who observes approved methods; the "good," "reliable" surgeon, who knows how to reduce dislocations, adjust fractures, tie arteries and treat wounds, to supervise the use of anesthetics, and to prescribe or conduct the after-treatment, who, after a careful examination, uses his best judgment and skill in operating, who is exacting as to prior assent, and who instructs nurse and patient as to conduct, while not immune, has little to dread in the courts.

Negligence consists in not doing the thing which ought to be done, or in doing that which ought not to be done:[2] in doing some act which a cautious and prudent man would not do, or in neglecting some act which a cautious and prudent man would not neglect:[3] in doing or omitting to do something which a surgeon of ordinary prudence and care would not have done, or would not have omitted to do, *under like or similar circumstances.*[4] The duty is dictated and measured by the occasion.[5] The degree of care must be in proportion to the known

apparent danger of the situation.[6] This does not mean that a slight case may be neglected. *Negligence* is the breach or omission, *the non-performance or the inadequate performance of a legal duty.*[7]

What the Surgeon Undertakes.—General Standard of Requirements.—A surgeon in practice invites the public to employ him, and *impliedly* promises that he possesses the requisite knowledge and skill and that he will use his best skill and judgment in treatment and subsequent care. He must have both knowledge and skill, and he must apply them. He is liable for want of skill and for failure to use it.[8]

He must *possess* and *exercise* such reasonable skill and diligence as are ordinarily possessed and exercised in his profession, *and regard must be had to the advanced state of the profession at the time.*[9] He must employ such skill and diligence as are ordinarily exercised in his profession *by thoroughly educated surgeons.*[10] He does not stipulate for the highest degree of skill, or that he is the equal of the renowned in the profession, but he must use the ordinary skill and care of the profession.[11] If he knows himself to be incompetent to treat the case, he should recommend another surgeon. If he knows that he is competent, but is uncertain as to the nature or extent of the injury, he must use his best judgment as to consultation.[12] In many cases care and skill are involved as much in the selection of the point of amputation as in the manner of performance.[13] If he attempts an operation as a specialist, as upon the eye, ear, or abdomen, he must have that degree of skill and knowledge which is ordinarily possessed by those who have made such operations a specialty, and he must exercise his best judgment in the application of his skill, and use ordinary care in the performance of the operation.[14]

Ordinary Skill.—What is meant by "ordinary," "proper," "reasonable" skill and care has been much discussed. Although a protest against a too high standard is to be found in an Iowa case,[15] where it was said "the average reasonable skill and diligence exercised by the profession as a whole" is the true measure, yet this has been denounced as an impracticable average. *The true rule* is that while not requiring the highest degree of skill, the law does require such skill as will bring proper and judicious treatment to the case.[16] Diligence, skill, and attention must be *adequate* to the performance of the undertaking; it is his own fault if he undertakes without sufficient skill, or applies less than the occasion requires.[17] The average is not to be struck by considering the uneducated, occasional, or officious. It must be the ordinary skill, learning, and experience of the profession generally,[18] tested by the *consensus* of surgical opinion as to what is proper under the circumstances, and, if disputed, must be established by witnesses of skill and experience as surgeons.[19]

Location to be Considered.—Country practitioners are not held to the degree of skill required of those having extensive city or hospital practice; but they must have the average skill and ability ordinarily possessed by surgeons *in similar localities.*[20] But this does not mean in a *particular locality*, where there might be but few,[21] and in an age of

surgical periodicals, improvements in instruments, and the use of antiseptics, they must keep pace with professional advancement.[22] *Gratuitous service does not absolve* from the duty to exercise reasonable and ordinary care, skill, and diligence.[23] The law guards alike charity patients and pay patients.

Additional Undertakings.—(*a*) **Must Obtain Consent to Operation.**—This has become of importance. In an early Massachusetts case,[24] where a cancer was removed, it was held that a surgeon is presumed to have authority to do all such acts as are in his opinion necessary, without notifying the husband of an intended operation or showing that the operation was necessary, or that it would be dangerous to wait, and so in an English case[25] Mr. Justice Hawkins charged a jury that there was tacit consent by the patient to a major operation, where, in the face of directions from the patient as to the removal of ovaries, the surgeon said, "you must leave that to me." This doctrine was justly criticized, for it is one thing for a surgeon to refuse to operate unless unlimited discretion be confided, and quite another thing to deliberately disobey express instructions. It would have been wise for the surgeon to refuse to operate unless the scope of his authority was agreed on in advance.[26] *The doctrine is now established that a surgical operation is wrongful and unlawful where performed without the express or implied consent of the patient.* A surgeon was consulted as to a difficulty in the right ear; after examination an operation was advised and consented to; under anesthetics it was found the left ear was in greater need. The family physician made no objection, and the operation was performed on the left ear. It was held that the operation was without the consent of the patient, and also that this was not an emergency case.[27] This doctrine has been confirmed.[28] The bodily integrity of a patient cannot be violated by a major operation without consent. Consent may be implied from circumstances. Unexpected conditions may develop or be discovered, and the surgeon must act on his discretion, according to the demands of good surgery, to preserve life. When an injury renders the patient unconscious and prompt surgical action is required to preserve life or limb, the surgeon must act, and consent will be implied *ex necessitate.*[29] The "emergency" or "danger," however, must be real. In a surgical operation upon a married woman it is her consent that is required,[30] and it is desirable to have that of the husband also; under special circumstances, other adult relatives being present, an operation may be performed on a minor without the express assent of the parent.[31] *Caution:* The reader is advised that, whenever practicable, it is best to obtain *written* consent from the patient, the husband, wife, parent, or nearest person in apparent control of the situation. Oral consent, while legal, may be denied, and the surgeon embarrassed by a contradiction. *Litera scripta manet.*

(*b*) **Must Obtain Consent to Autopsy.**—If an autopsy is performed without the consent of the person having a right to the custody of the body, the surgeon acts at his peril.[32] The only exception is where the *post mortem* is directed by law.[33]

(*c*) **Must Use His Best Judgment.**—If judgment be honestly exercised, infallibility is not exacted. Intelligence and care are required. The patient must be fairly dealt with. If an operation be unwise or unnecessary, the surgeon must say so, even though not asked. If the patient be of sound mind and mature years and persists, against advice, in demanding an operation, the surgeon may operate, and if he does so with skill, he is not responsible for having yielded *unless it involves dangerous consequences.*[34] But *consent* of patient should be put in writing. If there be symptoms of several diseases, he must balance possible results, and do that which he considers wisest under the circumstances, consulting, if he can.[35]

(*d*) **Must Follow Established Modes of Practice.**—The standard to be conformed to is that of the profession generally; otherwise experiment will supplant skill, and recklessness displace experience. If the case be new, the patient must trust to the skill and experience of the surgeon, but if there be an established mode, there should be no departure, unless the surgeon takes the *risk* of success.[36] An *established* mode is not necessarily confined to those stated in text-books.

(*e*) **Must Instruct Patient and Nurse.**—Necessary and reasonable instructions must be given to both nurse and patient as to treatment and conduct after an operation, so as to guard against consequences of careless nursing, or imprudence or impatience or premature efforts to use a limb or to return to work.[37] The duty does not end with the operation; advice and instruction must be given as to the care and use of an injured part of the body. *The instruction should be in writing.* The danger of neglecting this is illustrated by a recent case, where the patient denied the instructions, and in the conflict of testimony the surgeon was mulcted in damages.[38]

(*f*) **Must Continue in Attendance.**—The rule is fixed as to physicians that they must continue in attendance so long as the patient's condition requires it, and abandonment without leave or notice is inexcusable; it has been repeatedly decided that it is the duty of a surgeon to return after an operation to see how the patient is progressing, and that neglect to do so is a want of reasonable care and diligence.[39] As a corollary to this, in case of inforced absence, there must be a competent substitute.[40] The principal is responsible for the acts of the substitute, unless he be a man of experience and in independent practice who must answer for himself.[41]

(*g*) **Must Guard His Patient Against Contagion.**—This duty is imperative, and consists of care in the use of instruments and the acceptance of assistance; care of his own person, whether himself the subject of disease or a visitor to scenes of possible danger.[42]

(*h*) **Intoxication,** from any cause, while in attendance, if leading to injury or death, in some States will subject the surgeon to a charge of manslaughter; in others to a charge of criminal misdemeanor, while in all it would be regarded as negligence.[43]

(*i*) **Communications Not Privileged.**—A request to commit a crime, such as infanticide or abortion, must be firmly refused unless

necessary to save the life of the mother. The fact that such a request was made is not a professional secret which cannot be divulged.[44] This does not mean that the surgeon is to act as a detective or as a volunteer witness or as an informer. He must use his eyes and ears, but need not use his tongue in officious questions if the request be indefinite. If the crime be already committed and he observes the evidences of crime or attempted crime, *being himself free from participation*, he cannot avoid answering on the ground of privilege what a judicial officer, such as a coroner or committing magistrate, or the district attorney, may ask. A policeman or detective has not the right to interrogate him. If a surgeon catches an abortionist, or observes facts which may lead to his detection, he should communicate them to the district attorney, but he should not tell what was told him by the patient unless it be a dying declaration. Privilege relates only to what is necessarily communicated by the patient to aid intelligent treatment:[45] *it does not cover crime.* A mere apprehension that a crime may be intended calls for nothing but a warning to the patient. Voluntary revelations of secrets are a breach of honor and an indiscretion, but information required by the law to aid public justice cannot be withheld.[46] (See *Ante*, Sect. I., Privileged Communications, *et seq.*)

Restrictions on Liability.—The law does not require impossibilities. *If a fracture cannot be discovered* by a careful and skilful examination, because of conditions such as excessive swelling, the surgeon is not liable.[47] *Nor does the surgeon warrant a cure.*[48] He may make a contract to do so,[49] *but we warn him against such folly.* He never stipulates for success, at all events, and he is never to be tried by the defeat.[50] When he exercises his best judgment in a case of doubt, he cannot be held liable for want of success.[51] The implied contract is not to cure, to restore a fractured limb to its natural perfectness, but to treat the case with diligence and skill. The fracture may be so complicated that no skill can restore original straightness and length; or the patient may, by wilful disregard of the surgeon's directions, impair the effect of his best conceived measures. He deals not with insensate matter, but he has a suffering human being to treat, a nervous system to tranquillize, and a will to regulate and control.[52] So, too, he is *not responsible for an error of judgment*, unless so gross as to be tantamount to a want of skill,[53] *nor for violations of his instructions by a patient.*[54] If a patient contributes to an injurious result by his own behavior, by disregarding or violating instructions, the surgeon is not liable; so, too, if the patient's age or blood condition produces an unforeseen result.[55] *Nor where there is an intervening cause of death.*[56] *Injury must result from negligence or unskilfulness of the surgeon*, and the burden of proving negligence rests on the patient, who must be free from contributory negligence.[57] The surgeon *may refuse proffered assistance;* his refusal is an implied declaration of his ability to treat the case properly.[58] As has been seen (*ante*), he may refuse a case or withdraw on reasonable notice.

Responsibility for the Acts of Others.—This section is of

vital interest to the profession, but it is impossible to be specific, as cases will differ radically in their facts, and situations will vary with locality or emergency. Generally speaking, no one is responsible for the acts of another unless that other be so far in the employment of the surgeon, or so far under his direction and control, as to make him or her a mere subordinate, or agent, or instrument of the surgeon's will and judgment. Much will depend upon his opportunities of selection. If he selects his assistants and pays their charges or is responsible for their charges, he is undoubtedly responsible for all that they do or neglect to do. If they are in the exercise of an independent occupation, of fair reputation for skill and care, are selected by others and paid by others, and the surgeon has no reasonable opportunity of substituting others of his choice, it would take a strong case of negligence on his part to make him liable. If, on the other hand, he accepts those whom he knows to be unfit, or enters a hospital which he knows to be improperly equipped, and operates under conditions which his better judgment would pronounce to be unsafe, then, even though he had nothing to do with the employment or payment of nurses or assistants or the provision of instruments, he is negligent in accepting them and must take the risk.

The following points have been actually ruled: *He is liable* for the acts of his partner,[59] and if the partner dies, the action will survive against him. All surgeon partners are responsible for the negligence of any one of them in the partnership business.[60] A surgeon is responsible for want of proper skill in his apprentice or chosen assistant.[61] If he is about to operate at a hospital, he must know whether the hospital is equipped properly for such an operation, and he is charged with the responsibility of knowing that they are, at least, equipped up to the standard that the profession requires for the performance of such work. He must pass on the question of whether it is a proper place, and if he negligently makes a mistake, he is responsible. He may operate wherever circumstances *compel* him, and he may do the best he possibly can under the circumstances, and if he does that, and does it carefully, he is not responsible for disaster.[62]

He is not liable for injuries resulting from too great heat in a bath, ordered for a patient, and left to the nurse to administer, if he was not present and did not assist in preparing the bath.[63] He is not responsible for the acts of parents who attempted to nurse the patient and did not follow directions.[64] He is not liable for the carelessness of nurses unless his own carelessness in neglecting to instruct them contributed to the injury.[65] He is not liable for the negligence of nurses in a hospital over whom he has no control,[66] but he is liable for his own acts, although the acts of others may aggravate the injury.[67] He is not liable for injuries caused by the negligence of one called to take his place.[68] No case has as yet arisen in which it has been definitely determined as to a miscount by nurses of instruments and sponges; nor as to the use of hot-water bags at the close of an operation. The question will turn upon the extent, *under the circumstances*, to which the surgeon ought to

supervise. If the treatment be so closely connected with the operation as to form a part of it, it would seem that the surgeon is responsible for a burn. Where a surgeon is summoned to a distant hospital and the local doctor or hospital provides the assistants, it may well be regarded, so far as he is concerned, as an emergency case, and in the absence of knowledge on his part of the unfitness of those supplied, it would require the strongest evidence of negligence on his part to hold him. Of course, negligent assistants, nurses, and anesthetists are themselves responsible if they be worth the suing. This is an independent and not a substitutionary liability.

The desirability of insurance against these risks is a business question to be determined by the character and extent of the surgeon's practice.

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SUPPLEMENTARY MATTERS.

Duty in Cases of Crime.—But little need be added to what has been said under *Privileged Communications* (p. 1182) to define the duty of surgeons where they are casually or professionally present at a scene of crime. In this respect they stand like all other citizens so situated: they owe a duty to the administration of justice, and *must speak when called upon by the proper authorities.* In abortions or attempts to kill or maim they should act as informers—not against their patient—but against an apparently guilty third party. But it is knowledge and not suspicion that is to be communicated. No ethical consideration can affect this duty. In woundings, not committed in their presence, surgeons know nothing of the circumstances, and cannot tell what the patient said unless it be a dying declaration. The common law does not allow privilege in any case; the statutes in most States confine the privilege to *civil* proceedings, and even in those States where the privilege is not so limited, these results are established:

(*a*) Communications for the purpose of an unlawful act are not protected,[1] the only exception being that the life of a child may be sacrificed, *when necessary*, to save the life of the mother, and as to this there should be, if possible, a consultation—at all events, *no secrecy*.

(*b*) The privilege being for the welfare of the patient, cannot be invoked by the criminal by way of defense.[2]

(*c*) *After the commission of crime*, knowledge obtained from the sufferer during professional visits is privileged, if the patient be indicted.[3]

(*d*) Whether the death of the patient would unseal the lips of the surgeon is undetermined, but it would seem that if speech cast dishonor on the dead, silence would be enjoined unless it impeded justice.[4]

(*e*) The only places where silence can be broken are courts of justice, at coroners' hearings, or before committing magistrates.

(*f*) Nothing less than the interests of *public justice*, as above indicated, will justify a breach of professional confidence or the disclosure, by means oral, written, or published, of professional secrets.[5]

(*g*) A surgeon is not the gaoler of his patient, and hence, unless he should *connive* at an escape, he would not be responsible if a wounded man, under his care charged with crime, should escape or jump his bail.

Ethical Considerations.—The law has not spoken upon the matter of *private* communications *to parties interested*, of the existence of secret, loathsome, and dangerous diseases in nurses, attendants, or those about to marry. The problem is ethical. There would seem to be but little difficulty, however, in sustaining the conclusion that the communication could not be regarded as a proper subject for legal condemnation, if communicated upon request or in confidence to the medical or surgical adviser of the innocent party. Similar confidential communications are often made respecting the integrity and capacity of proposed employés, without the risk of damages. A statement as to syphilis in a nurse made to the parent of an infant would be proper;

but a statement to the father of a bride to be as to disease in the husband to be stands on no legal ground of duty. Ethics must govern. At present the function of the surgeon is to treat, rather than to prevent, except where his duty is clearly defined by health regulations.

Business Considerations.—*The surgeon should keep books* in which to enter his charges for services; the entries should be made daily, under the exact date, and show the name and residence of the party charged, the character of the service, and the amount of the charge. No hieroglyphics, abbreviations, or unintelligible marks should appear. If the party charged should die, and a claim be made against his or her estate, the books, if not daily records, or if unintelligible, would be useless as evidence, and the claim be lost, because a living claimant cannot personally testify against a dead person. The contest would be unequal. If properly kept, the books would sustain the claim.

The person to whom the service is rendered is the party primarily liable. A husband is responsible for the services rendered to his wife unless she be separated from him without just cause. A father is responsible for necessary services rendered to minor children; if the father be dead, the mother is liable if she have a separate estate and the minors have no estate; if there be such an estate, the bill should be sent to the guardian. No one is responsible for the debt of another unless he agree to be so in writing, signed by him or by his duly authorized agent. A mere messenger to call the surgeon is not responsible for the bill; an employer is not liable for his injured employé, unless he say in plain terms, "attend my employé and charge the bill to me." If he say, "attend him, and if he does not pay you, I will," he is not responsible unless the engagement be in writing.

The Employers' Liability Statutes do not make the employer liable to the surgeon. Though surgeons' bills often constitute an item of damage in a suit brought by an injured employé, yet the liability of the employé to the surgeon is direct—and legally the surgeon and the employer are strangers to each other, unless there be such an arrangement as is stated in the preceding paragraph.

Drawing Wills.—Nothing but grave emergency will justify a surgeon in drawing a will for a patient. If legal assistance can be had, it should never be dispensed with. If the testator be *in articulo mortis*, write down the exact words as dictated, have the testator sign *at the end* of the writing in the presence of at least two *subscribing* witnesses, *free from the taint of interest as legatees.* Never be persuaded to write a will under which you are a beneficiary. Remember your relation to a patient is like that of a spiritual adviser or lawyer,—a confidential one,—and the law will not permit confidential relations to be abused. The burden of explaining away an advantage to yourself is often too heavy to be carried, and defeat and disgrace follow in the court all such efforts to profit by the weakness of the patient. A grateful patient may reward a surgeon by a legacy, but let a stranger's hand draw the will *in the absence of the legatee.*

It is proper to act as a *subscribing witness to a will* in which you are not interested, if requested either by the testator or the legal draftsman, but remember that you should not do so unless satisfied of complete testamentary capacity and can withstand cross-examination on that point.

Never intrude a non-professional stranger as a witness to an operation where exposure of the person is involved. Such an act, in a confinement case, mulcted an obstetrician in damages.[6]

The Law of the Road.—The surgeon, driving himself, or driven by his own coachman, is responsible for careless driving. He has no right, while endeavoring to relieve an injured person, to add to the list of casualties. He has no right of way, such as a patrol wagon, or a hospital ambulance, or a fire engine, all of which give loud notice of their coming. The rights of others on the road, and of pedestrians at crossings, are equal to those of the patient, and the sound man should not be maimed for the benefit of one already injured. Of course, other drivers and pedestrians are bound to be vigilant and careful. If both colliding objects are at fault, there can be no recovery from either. The legal rule is that all persons on a highway must exercise the caution and care which an ordinarily prudent person would exercise *under the circumstances.* A pedestrian ought not to walk right in front of an approaching carriage, or take the risk of getting across in time; on the other hand, no one has a right to drive over one, who, though on foot, has fairly started on a crossing to which he is entitled; crowded, narrow, or dangerous crossings must always be approached with care.

Witnesses to Accidents.—Except to enable him to testify clearly, accurately, and impartially as to the circumstances, no surgeon, unless in the employ of the company sued, need busy himself in obtaining the names and addresses of witnesses to an accident, and even if he be in the employ of the company, he should be careful not to act as a partisan in securing evidence or working up a case for either side; nor should he attempt to negotiate settlements or pay money. The surgeon's functions are not those of a claim-agent. If the accident be one in which the surgeon's own carriage is involved, it would be wise for him to secure the names and addresses of the eye-witnesses.

Insurance.—The desirability of insurance, whether life, accident, health, or team insurance, or against the consequences of infection, presents a business question which each man must settle for himself according to his means and the necessity of indemnity against risks which are common and sufficiently serious to deserve consideration. The character of the risks covered by policies depend on the language used, and the matter should be submitted to legal advisers before premiums are paid.

Financial Arrangements.—This, too, is mainly a question of business, involving knowledge of human nature and tact. Some people would resent an attempt to pin them to a bargain; others would prefer it. An oral contract is as legal as a written one, but the written one is always capable of easy proof, while the terms of an oral one may

be disputed. If there be room for sufficient distrust of the patient to suggest a contract, by all means let it be written. If the patient invites it, the way is easy, but the suggestion of it to one of means and character would be unwise.

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CHAPTER LXXXV.

THE LABORATORY AS AN AID TO SURGICAL TECHNIC AND SURGICAL DIAGNOSIS.

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This article is not intended to present the various technical applications of the pathologist and laboratory worker, but to indicate to the surgeon methods by which, in correlation with his usual resources, the laboratory may be found useful. A certain degree of familiarity with laboratory technic and methods is constantly helpful to the surgeon, and for such information he is referred to the works of Sahli,[1] Emerson,[2] Simon,[3] Wood,[4] and Lenhartz[5]; for more exact data concerning clinical diagnosis, Ogden's[6] excellent work on the clinical examination of the urine will be found of value. For blood studies the monographs of DaCosta[7] and Ewing[8] may be consulted. The necessary information in bacteriology may be obtained from the works of Kolle and Wassermann,[9] Macé,[10] Miquel and Cambier,[11] Muir and Ritchie,[12] and McFarland.[13] Mallory and Wright,[14] Lee,[15] Cattell,[16] and several current works on pathology contain all the details of routine pathologic technic.

For the purposes of this paper I shall consider—(1) Laboratory control of operative technic. (2) Procuring and handling specimens intended for laboratory diagnosis, with suggestions as to technical points. (3) Definitive preservation of specimens for the museum and for teaching purposes.

Laboratory Control of Operative Technic.—It is the experience of almost every surgeon that, at some time during his career, infections occur in such numbers as to indicate strongly some defect in technic. When such misfortune befalls an operator, it becomes necessary for him to investigate his methods, conducting the inquiry in as orderly a manner as circumstances will permit. Experience has established that in many instances the difficulty results from imperfect sterilization of the hands of the operator or assistant. For the purpose of determining this source of error, or for guarding against it, the skin of the hands, and preferably the fingers, especially the subungual spaces, should be examined. A culture-tube containing sterile bouillon and possessing a diameter sufficient to admit a finger is selected; the sterile cotton plug is removed and the lip of the tube disinfected by passing it through the flame of a Bunsen burner or alcohol lamp; the fingers, one after another, are introduced into the tube, which is so tilted as to bathe the digit which is sloshed about in the fluid and rubbed against

the wall of the tube, thereby introducing any bacteria which may be adherent to the finger or contained in the epithelial cells detached by friction against the inner wall of the tube. The cotton plug is quickly restored and the tube labeled and forwarded to the laboratory for incubation. As this method often fails to remove bacteria deposited under the nail and dislodged with difficulty, it is advisable to make cultures directly from the subungual spaces; for this purpose a heavy platinum wire—readily sterilized by flaming—may be passed under the nail and around its margin and washed off in the sterile bouillon.[17] In a similar manner sterile hard-wood sticks—preferably orange wood—may be used to clean the nails, after which they are thrown into the bouillon. The objection to articles of vegetable material lies in the great difficulty in securing primary sterilization. A growth in any of the culture-tubes indicates inadequate disinfection, but it is important to determine the nature of the growing organism, as the clinical evidence —infection—must depend upon the presence of pathogenic, usually pyogenic, bacteria. During all these steps it is important that no germicide shall have been introduced into the culture-medium in sufficient quantity to inhibit the growth of any viable organism. In 1903 Professor Keen introduced this method into the clinics of the Jefferson Medical College Hospital and found it an efficient control, especially for assistants and nurses, upon any one of whom a succession of positive findings would cast a distinct reflection. Cultures were taken from the hands of the surgeon and every assistant and nurse at all the weekly clinics in his service. The following table shows how such a record may be kept; a growth is indicated thus +:

RESULTS OF BACTERIOLOGIC EXAMINATION OF HANDS—SURGICAL CLINIC.[1]

Inoculations from Hands of	January.					February.				March.			
	2	9	16	23	30	6	13	20	27	6	13	20	27
Surgeon A...	—	—	—	—	—	+	—	—	—	—	—	+	—
Surgeon B ..	—	—	—	+	—	—	—	—	+				
Surgeon C...													
Surgeon D...										—	+	—	—
Surgeon E...										—	—	—	+
Nurse 1		—	—	—	—	+	+	—	—	—	—	—	+
Nurse 2													
Nurse 3													
Nurse 4													
Nurse 5.		—	—	—	+								
Nurse 6.		—	+	—	—						—	+	—

It may also be important to determine whether the preparation of the field of operation has been such as to produce a sterile surface. In order to test this a sterilized cotton swab is rubbed briskly over the skin and then placed in bouillon, or the skin may be scratched or scraped

[1] Negative —; Positive +.

and the fragments so obtained introduced into the culture-medium. Epithelium almost constantly contains bacteria not reached by any known method of cutaneous disinfection, and, therefore, the second test usually yields positive results; where, however, the scraping has been light and superficial, a negative finding should be obtained.

It is also necessary from time to time to investigate the sterility of instruments and materials used during operation. Instruments may be moved to and fro in sterile bouillon or allowed to remain in the medium for at least half an hour. Fragments of dressing material, gauze sponges, catgut, and silk or other suture and ligature substances may also be placed in the bouillon and kept under observation for a sufficient length of time for the growth of any contained viable organism. It is especially with regard to catgut, silkworm-gut, and tendinous substances that the greatest care is necessary; catgut exposed to the action of body juices usually softens and eventually disintegrates; such

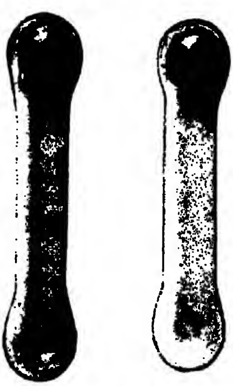

FIG. 538.—CAPSULES FOR CONTROLLING THERMAL DISINFECTION. (Exact size.)

These capsules consist of a firm outer shell of glass containing a fusible metal and as little oxygen as possible. They are placed in packages with the fusible metal at the upper end. After sterilization, if the penetration of the heat has been adequate, the metal will be found at the lower end of the capsule. Capsules containing shaped masses of metal may also be used. They possess no great advantage and are expensive, because a new one is required for each sterilization. The capsule represented in the illustration can be used a number of times.

softening and disintegration do not take place in the usual culture-media, particularly those containing sodium chlorid, and for this reason the test-tube experiment is not exactly comparable to the results obtained in wounds. Hallion and Carrion[18] have called especial attention to the difficulty in removing from catgut residual disinfectant and securing in cultures sufficient disintegration to liberate contained bacteria; they recommend that the gut be transferred from tube to tube through at least three passages, thereby removing any adhering antiseptic, and facilitating the swelling and separation of the tightly compressed strand. The test should not be restricted to a single fragment or even a short piece, but should include a number of specimens from different strands. The fact that catgut and similar substances may contain anaërobic bacteria, such as the tetanus bacillus and organisms of acute gaseous gangrene[19] and gangrenous suppurations,[20]

renders it necessary to determine the presence of pathogenic anaërobic bacteria, which may be accomplished by the usual anaërobic methods. In certain instances animal inoculation is necessary.

A not infrequent source of failure to obtain asepsis is the inadequate heating of bundles and packages in various sterilizing devices. This danger may be partly overcome by the use of properly placed registering thermometers, or by glass capsules (Fig. 538) containing fusible alloys, the melting-point of which corresponds to the temperature desired.[21]

An occasional source of infection is the incomplete sterilization of water used in the preparation for operation or in the operating-room. Of the many devices supplied for the purpose, none is absolutely free from the dangers of faulty technic. For determining the efficiency of such sterilization 2 to 3 cc. of the suspected water should be added to bouillon and the resulting mixture incubated. Normal salt solution and other artificial sera may be similarly studied. When examining antiseptic solutions it is well to bear in mind that some waters contain substances that render inactive the agent upon which effectiveness depends and also that mistakes in compounding are possible. In either case the fault may be detected by the methods commonly employed for testing the efficacy of disinfectants. Klein[22] has pointed out special sources of technical error.

Procuring and Handling Specimens Intended for Laboratory Diagnosis, with Suggestions as to Certain Technical Points.— To the surgeon anxious to improve his diagnostic skill nothing is more important than the careful examination of specimens during and after removal; the information secured in this way may be rendered more valuable by correlating the data obtained by macroscopic examination with those secured through a careful histologic study. As Bloodgood[23] wisely observes, "the surgeon of the future must be his own pathologist." In no way may diagnostic skill be more rapidly advanced than by a careful and judicious comparison of clinical facts with the morbid anatomy, including the morbid histology, of excised tissues, and to these should be added a properly conducted bacteriologic investigation. There can be no doubt but that the best results are to be obtained by the coöperation of surgeon and laboratory technician familiar with the methods of investigation especially adapted to any particular case.

The modern methods of laboratory research have become, to a large degree, highly specialized, and partake of the nature of chemical and physical examinations as accurately conducted by specialists in those departments of science. So far has this method advanced that even the staining of tissues is now known to be a definite chemical process, the best results afforded by combinations and reactions as accurate as those utilized by the chemist for the separation of arsenic from organic compounds. A misstep in the preliminary treatment of a specimen may forever preclude a complete microscopic examination.

The specimen sent to the pathologist should be accompanied by specific data stating what the specimen is or what it is supposed to

be, its origin, whether obtained antemortem or postmortem, the date and hour of its removal, the name, age, sex, social condition, nativity, nationality, color, occupation, and race of the patient. The clinical diagnosis, or at least a suggestion as to the nature of the lesion, should also accompany the specimen. If the material has been submitted to the action of any chemical agent, or is transported in any medium, the pathologist should be advised. The inexperienced sometimes surround the specimen with an air of mystery refusing all clinical data, and often fail to state from what part of the body or from what organ the specimen was obtained. In such cases the pathologist must roam through the domain of conjecture and, by a circuitous route arrive, if possible, at some conclusion.

FIG. 539.—WARREN'S STERILIZED TEST-TUBE CONTAINING SWAB. (Mallory and Wright.)

In many instances it is wise for the surgeon and pathologist to consult as to the probabilities, and in advance decide upon some line of study suggested by the evidence. For example, in elephantiasis of the scrotum, or in lymph varix, a careful dissection of the excised tissue may disclose an adult filaria which in the fresh specimen may be floated out in saline solution and fully studied; after indiscriminate incision or definitive fixation such a result is scarcely possible. Certain substances are specifically adapted to definite fixation and preservation of particular structures, and yield satisfactory results when examined by one method, but are unsuited to any other. For these reasons the primary treatment of a specimen may determine the technical limitations employed in the laboratory. Just as the chemist wishes material in its raw state, unchanged by treatment, so the pathologist should be unfettered by the injudicious application of agents that may deleteriously influence or render impossible a special line of investigation.

Material intended for bacteriologic study must be collected in such a way as to preclude accidental contamination—the addition of extraneous organisms—which may invalidate the diagnostic conclusions indicated by the findings. One of the commonest sins in this respect consists in sending to the laboratory specimens of urine, pus, or other fluids in unsterilized containers (bottles, etc.). Excised tissues after handling by infected hands, or deposited on bacteria-laden tables, or wrapped in paper or other germ-carrying material, can scarcely yield a satisfactory or trustworthy result. The bacteria derived from such sources are commonly rapidly growing saprophytes that, when subjected to cultivation, outstrip the pathogenic organisms with which they are mixed, and often preclude isolation of members of the latter group. Specimens supposed to contain germs difficult to obtain in pure

culture, such as the gonococcus, meningococcus, and tubercle bacillus, require the greatest care. Contamination also interferes with animal inoculation; a specimen supposed to contain tubercle bacilli may be rendered useless for inoculation by the introduction of pyogenic cocci that kill the inoculated animal before experimental tuberculosis has time to develop. Another all-important consideration is the exclusion of antiseptics which may kill contained bacteria or be carried into culture-media and inhibit growth; for this reason containers (bottles, etc.) used for collecting specimens to be examined bacteriologically should be sterilized by heat and not by chemical means.

For the collection of material for bacteriologic examination an ordinary test-tube, plugged with cotton and sterilized, may be used. It is somewhat unwieldy, and the inexperienced often find the introduction of fragments of tissue or fluids difficult. The sterile tube containing a swab (Fig. 539) is more convenient; by rubbing the swab over infected surfaces and then applying it to the medium in a culture-tube, an inoculation is readily made. It should be prepared by tightly wrapping the tip of a stiff aluminum wire with absorbent cotton and applying a second mass of the cotton of sufficient size at a point where, when introduced into the tube, it will act as a closely fitting secure stopper; the tube containing the swab should be sterilized in the hot-air oven at 140° C. for twenty minutes. The device for collecting fluids (Fig. 540) consists of a dropper and tube; the rubber of the dropper precludes hot-air sterilization; steam may be used or the glass and cotton parts may be sterilized in the hot-air oven and the rubber part in steam, the two being assembled immediately upon removal from the sterilizers.

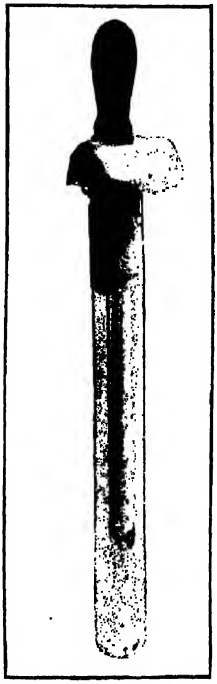

Fig. 540.—Apparatus for the Collection of Pathologic Fluids. (Mallory and Wright.)

Inoculations may be made with the ordinary platinum wire mounted in a glass rod, a sterile knife, ligature carrier, or probe, preferably sterilized by heat, heavily laden with the suspected material, and rinsed off in the sterile bouillon or other liquid medium, or rubbed over the surface of agar or some form of solidified blood-serum. Frequently the bacteria are not numerous, and often when plentiful all do not grow; it is, therefore, important that an abundance of material shall be planted; furthermore, a large quantity enables the laboratory worker to make other inoculations whenever the medium primarily used is not adapted to the growth of the organism thought to be present.

The best bottles for collecting aseptic material are those shown in Figs. 541 and 542. The former, known as the aseptic bottle of Lafay, possesses a carefully ground overhanging mushroom stopper and a ring

on the side of the neck, rendering it possible to tie a pad of sterile gauze over the stopper, which is thereby kept in place, and at the same time infection of the lip of the bottle is rendered improbable; the interior of the bottle is without angles and inaccessible corners difficult to clean; the most convenient capacities are 50 and 100 cc. The chemists' weighing bottle (Fig. 542) is small, light, easily dipped into cavities, and readily cleaned and sterilized. In the absence of such ideal devices ordinary glass-stoppered salt-mouth bottles thoroughly sterilized may be used.

For convenient transportation of media, sterile tubes, bottles, etc., wire baskets (Fig. 543) are most useful. A towel is placed in the

FIG. 541.—THE ASEPTIC BOTTLE OF LAFAY. (Two-thirds natural size.)

The mushroom stopper may be secured in place by a hood of sterile gauze, tied in position by a string applied below the ring in the neck of the bottle.

FIG. 542.—CHEMISTS' WEIGHING BOTTLE, ESPECIALLY ADAPTED TO COLLECTING FLUIDS.

It is made of test-tube glass, may be sterilized by any satisfactory method, and the numbered stopper and body offer convenient aids in keeping records.

bottom of the basket, to prevent jolts from breaking the tubes, and two superimposed towels drawn over the top and tied with a bow-knot, as shown in the illustration. The basket and its contents are sterilized and sent to the operating-room; when the operation is about to begin, the knotted cord is untied or cut and the uppermost towel removed, leaving a single sterile towel that may be handled by the operator or his assistants, whose hands have been disinfected. A single basket may contain tubes of different media, either labeled, which is difficult, or indicated by spotting the cotton stoppers with drops of anilin dyes, always using the same color for each medium. Sterile tubes and bottles may be kept in the same basket. It is desirable, but not necessary,

that a fresh basket be available for each operation; confusion is, thereby, avoided, and the tendency to accidental contamination lessened. All tubes and containers used should be labeled before being returned to the basket. Various forms of bacteriologic pocket cases or outfits have been devised, but I am unfamiliar with any that can be cordially indorsed.

In every case spreads[1] of suspected material should be prepared, as —on account of cultural difficulties or for other reasons—the bacteria present may not be obtained in culture, or the organisms that grow may not be the important infecting agent; this is especially true of open wounds and exposed ulcers. Spreads may be made on cover-glasses or slides; they must be thin and uniform, and should be at once forwarded to the laboratory. The cover-glasses may be sent to and from the

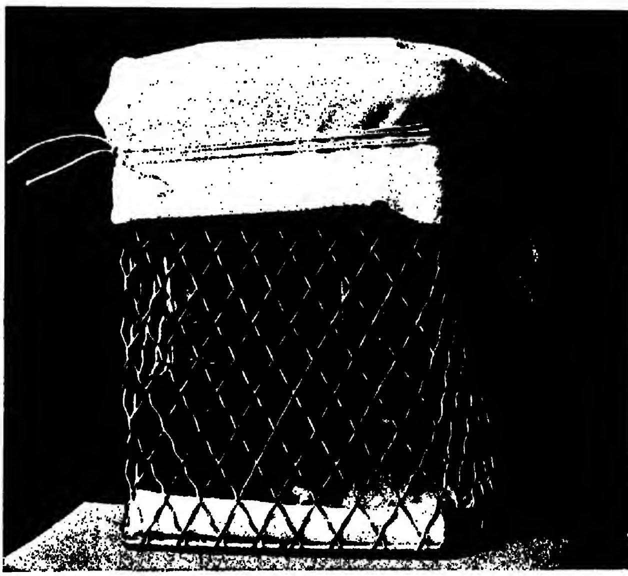

FIG. 543.—WIRE BASKET CONTAINING TUBES OF MEDIA AND STERILE COLLECTING TUBES PREPARED FOR OPERATING-ROOM.

laboratory in sterile tin ointment boxes, and the slides, after drying, may be wrapped in sterile gauze; in both cases labeling must not be forgotten. A slide, one end of which is ground for easy pencil labeling, may be obtained from dealers; it is inexpensive and convenient, and may be cleaned and used repeatedly. When spreads are not made at the operation, they should be prepared in the laboratory immediately on receipt of the container, using for the purpose the excess of deposit insisted upon above. In addition to the information secured with regard to the bacteria present such films yield valuable data concerning the contained cells and pigments, and may disclose ova or other elements indicative of animal parasites; the amebic or echinococcal origin

[1] "Spread" is a term used in the laboratory to designate a layer of any substance to be studied, laid down as the thinnest possible stratum on a previously thoroughly cleaned cover-glass or slide.

of an hepatic abscess may, in some instances, be established by the examination of fresh or dried and stained films; for animal parasites the former are preferable. If, for any reason, cultures are not made, films may be of value in determining the presence of bacteria, and also, in a general way, the type of germ. Schauta, Howard A. Kelly, and Penrose have recommended the immediate examination of stained films and weighing the information so obtained when considering the necessity for drainage. The plan is defective in that dead or no longer viable or pathogenic bacteria may be found, but in the hands of discerning clinicians it possesses a certain value. Kelly[34] no longer uses the method.

Tissues Removed for Diagnostic Purposes—Rapid Examinations.—In a small number of cases the surgeon wishes to learn the histologic diagnosis before proceeding to operation. For this purpose many methods by which small pieces of tissue can be removed have been devised. A harpoon has been used; Warren employed a punch resembling a cork-borer, which was thrust into the tissue, slightly withdrawn, so as to change the direction, and again pressed forward, thereby cutting off and withdrawing a cylinder of tissue which came away in the cannula-like instrument. Webb[25] recommends a suction device that pulls up into the lumen of a tube a small piece of tissue, which is then snipped off. Schupfer[26] uses a trocar-like needle 8 cm. long and possessing an internal diameter 1 to 1 5 mm. This he attaches to a Luer syringe, and after the needle is passed through the skin the piston of the syringe is withdrawn, creating a vacuum, which, as the needle is thrust forward, leads to a piece of the tissue being pressed into its lumen. After withdrawal the fragment is ejected by air forced into the needle from the syringe. Probably no instrument is better than a sharp knife or a pair of scissors possessing knife-edges; in inaccessible cavities, such as the uterus, a curet may be employed or, for the rectum, a special type of scissors-like device. Gouges, punches, and similar appliances mash and distort the tissue, thereby rendering it unsuitable for the best results. It is to be remembered that structure rather than cell is the important feature to be determined, and that any method that materially alters relations of elements—disturbing the architecture, if I may use the expression—is to be condemned. For the same reason the surgeon should avoid the crushing action of forceps and handle the fragment with the greatest care. Many times the specimen is too small, is composed of blood-clot, or is necrotic and cannot be stained satisfactorily or does not represent the essential pathologic tissue, and in any case yields no conclusive result. That it is not representative is a frequent source of error, and the difficulty besetting the surgeon may be partly realized by the following case: A patient presenting a small ulcer on the tongue was admitted to the Jefferson Hospital, and the attending surgeon decided to subject a fragment to microscopic examination. The tongue was held and scissors applied for removal of a small piece, but an unexpected movement of the patient resulted in the excision of nearly the entire ulcer—

about 1 cm. in diameter. As is usual, the entire mass was cut in serial sections and every tenth to fiftieth section mounted and stained; one side of the ulcer was clearly cancerous, the other margin showed no evidence of malignancy. A small fragment or less complete examination might easily have led to a wholly erroneous diagnosis. Uterine curetings are most troublesome in this regard.

It is also important that the sections be cut in such a plane as will best disclose the pathologic condition, and especially, where possible, its relation to contiguous normal or but slightly altered tissue. For this reason the fragment should be handled by some one familiar with its surfaces, or, to use the proper technical term, one able to orient the tissue and obtain sections in the most desirable plane; in all cases this is advisable, in some not necessary, and in others impossible. Whenever possible the specimen should be sent to the laboratory immediately after removal and without treatment or handling. Small fragments should be forwarded in glass containers and not wrapped in gauze, cotton, or other material in which they are readily crushed, to which they adhere tenaciously, or are in other ways injured. Larger specimens may be wrapped in sterile gauze. When immediate delivery at the laboratory is not possible, the specimen may be placed in a solution composed of commercial formalin, 10 parts, and water, 90 parts, in which fluid it may remain for a number of days without injury. When in doubt regarding the nature and extent of the investigation necessary, and circumstances are such that the specimen cannot be delivered to the pathologist at once, the surgeon should learn in advance exactly what fixing agent is to be used.

Having obtained the fragment of tissue and knowing the importance of an early report, what method should be selected? After a long experience with freezing methods I think they may be condemned for this purpose, especially when, under proper conditions, paraffin may be satisfactorily used. Fix the fragment in a saturated solution of corrosive sublimate in alcohol for one hour; transfer for the same period to each of the following, in the order named: (1) Absolute alcohol; (2) absolute alcohol and xylol, equal parts; (3) xylol; (4) paraffin at 50° C.; (5) second paraffin at 50° C.; cast and ice; immediately section, mount, and stain. If the fragment be small, all the sections may be mounted; if large, every tenth or twentieth section is selected, and in either case a full view of the tissue is obtained, the entire process occupying not more than six to eight hours.[27] For this work I wish especially to accentuate the value of serial sections: a large number may be more fully studied; different stains applied; bacteria sought, and the fragment so built up in the observer's eye that the possibilities of a correct diagnosis are greatest and the opportunity for misinterpretation reduced to a minimum.

Freezing methods have been strongly urged as applicable for immediate diagnosis of excised specimens and for diagnostic aid at operation. Since Cullen's paper,[28] the most important methods described are those of Cullen modified by Hodenpyl,[29] and the older freezing method

recently advocated by Shaw[30] for rapid work, and the somewhat slower but far superior technic advised by Wright.[31] The methods used by Gutmann,[32] Stein,[33] Pick,[34] and Kent[35] are preferred by some. A good freezing microtome—Bardeen's is best—and some experience in its use are necessary; the freezing may be accomplished by ether, rhigolene, liquefied carbonic acid gas, or, as recommended by Cattell,[36] ethyl or methyl chlorid. A few minutes' submersion in 10 per cent. aqueous solution of formalin is very helpful; if the specimen is to be taken from the operating-room to the laboratory, it may be kept in the formalin during the time necessary for its transportation; even in this brief period some fixation and hardening are possible. A drop of a syrupy solution of gum arabic is placed on the microtome drum, and in this the fragment of tissue is oriented; freeze and cut, and transfer sections to a dish of cold water in which they are separated. A selected section is dipped in alcohol and at once transferred to a dish of cold water, in which it floats and flattens out. A slide is dipped under the section, thereby lifting it out of the water, the excess of which is removed by bibulous paper or cloth. Hematoxylin and eosin may be used, but require more time than methylene-blue, as recommended by Shaw.

For diagnostic purposes the freezing method cannot be considered satisfactory, and is far inferior to the serial sections recommended above. I know of a number of instances in which calamitous results followed the acceptance of such hurried diagnoses at operation. In spite of these sources of error, however, many surgeons, recently Lockwood[37] especially, regard the freezing method as decidedly helpful.

Urine, pus, exudates, and similar liquids should be sent to the laboratory fresh, or, if some hours must elapse, the container should be placed in ice. If cultures or inoculations are to be made, no antiseptic is permissible, and if chemical examination is desired, most preservatives are possible sources of error. Ogden[38] concludes that the best preservative for urine is boric acid, in the proportion of five grains to the ounce; one drop of formalin to four ounces of urine may be tried; larger quantities are not permissible.

The Definitive Preservation of Specimens for Museum and Teaching Purposes.—Specimens intended for permanent preparations should be sent to the laboratory at once; icing, refrigeration, or preliminary treatment of any kind is to be avoided. Immediately upon delivery the specimen is arranged just as it is desired to be exhibited; the surfaces are then gently washed to remove adhering blood, but must not be water-soaked. The entire mass is immersed in a fixing solution having the following composition:

Formalin (any 40 per cent. aqueous solution of formaldehyd gas serves equally well)	250 cc.
Potassium nitrate	10 "
Potassium acetate	30 gm.
Water	1000 cc.

After from one to twenty-four hours, depending upon the size and especially its thickness, the specimen is transferred to a fresh

solution of the same composition, in which it is left for an equal period of time. The fixation fluid is removed by washing in running water, or by several changes of water, for fifteen to thirty minutes, and is then developed by passing through two changes of alcohol. As soon as the color lost during the fixation is fully restored, the mount is removed from the alcohol, mopped with a towel, and placed in a final preservative composed of acetate of potassium 200 gm., glycerin 400 cc., and water 2000 cc. As prolonged immersion in any solution exerts a bleaching action, and as Littlejohn[39] has shown that satisfactory preservation in air-tight containers is possible, the specimen may be placed in a jar and accurately sealed; aside from the condensation on the inside of the jar and the difficulty in retaining an air-tight seal, this method is fairly satisfactory. The best results are obtained by permanently mounting in rectangular jars in a medium composed of the final preservative mentioned above, rendered solidifiable by the addition of 10 per cent. gelatin. As gelatin liquefies at comparatively low temperatures, it is necessary to add, immediately before use, 0.75 cc. of formalin to each 100 cc. of this mixture. The details of the method just given I have published elsewhere.[40]

Rowntree,[41] after trimming and arranging the specimen, fixes it in a fluid having the following composition:

Sodium sulphate		20 gm.
Sodium chlorid		10 "
Magnesium sulphate		20 "
Formalin		50 cc.
Water	to make	1000 "

It is applied in practically the same manner as the fixation fluid mentioned above. For developing he uses methylated spirit diluted one-half with water during the first twelve to twenty-four hours, and later, for an approximately corresponding period, full strength. The specimen is then transferred to a solution consisting of sodium acetate, 20 gm.; glycerin, 500 cc.; water, 500 cc., in which it remains two to three days, followed by pure glycerin for forty-eight to seventy-two hours, and finally is placed in paraffin oil, the liquid paraffin of the British Pharmacopeia. Dr. Howard T. Karsner exhibited at the Philadelphia Pathological Society a number of specimens prepared by this method. For the final preservative he uses an exceptionally clear paraffin oil called glycerinum petræ. The oil, like gelatinized solid media, does not extract the color and is much clearer; it appears, therefore, to have some advantages.

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CHAPTER LXXXVI.

THE SURGICAL ORGANIZATION OF A HOSPITAL.

By Albert J. Ochsner, M. D.,

Most surgical departments of hospitals at the present time must be organized with a view to supplying proper facilities for performing many varieties of surgical work by a number of relatively independent surgeons who are active in the same institution. The best possible organization under such conditions must be exceedingly bad, because of the fact that there cannot be any individual system developed which will be acceptable to every one whose position entitles him to equality as regards authority. More than 95 per cent. of all hospitals, with the exception of private enterprises in English-speaking countries, are organized upon this plan of having a large surgical staff without an active head, hence it will be necessary to plan the organization on this basis.

The Visiting Staff and their Assistants.—The visiting staff of a hospital containing not more than four hundred surgical beds should never consist of more than four attending or visiting surgeons, in order that the patients may be directly under the care of men who have a sufficient amount of work in the institution to make it worth while to take a desirable amount of responsibility. If each surgeon's division contains more than thirty beds, it is well to conduct it as a separate unit, with a separate assistant visiting surgeon and a separate resident surgeon for each unit, because this number of patients is sufficient to keep one resident surgeon reasonably engaged, and by making a separate department, there is a possibility of thorough systematizing.

The department should be organized as follows; one visiting surgeon; one assistant visiting surgeon; one resident surgeon for every thirty to fifty beds in the department. If the hospital is only large enough for one resident, his term of service may be for any desired time not to exceed three years. In case there are two, it is most convenient to have the service arranged for one year with a senior and junior service, a new resident surgeon coming on duty every six months. It will be equally convenient to have a longer service, one-half being given to junior, the other half to senior work. If three residents are required, it is well to arrange the service for eighteen months, with one new resident surgeon going on duty every six months.

The service of members of the visiting staff should be continuous, in order that a uniform system may be developed. During the vacations of the visiting surgeon, the assistant visiting surgeon will naturally continue the system of his chief, so that there will be no interruption in the development.

In each department the responsibility should rest on the visiting surgeon, who should personally visit every patient three times each week at least, and should invariably examine every patient within forty-eight hours after admission, and as much earlier as possible. Either he or the assistant visiting surgeon should personally examine every patient who enters the hospital seriously ill at once upon admission and before an operation is performed or active treatment is begun. In case neither of these surgeons is obtainable, then a visiting surgeon from another department should be called, who should take charge of the case temporarily in case an immediate operation must not be performed. In case an immediate operation is indicated by the existing condition, then the patient should remain permanently under the care of the surgeon performing the operation, in order to make the after-treatment accord with the conditions required, as indicated by the conditions found and corrected at the time of the operation.

It is important that these cases receive the personal attention at once of surgeons of experience, instead of being left during this critical period in the hands of inexperienced house officers. At this point it is well to state that the latter will profit much more by assisting their chiefs in treating these serious cases than if they were to undertake the treatment independently.

In order that this duty of visiting the serious cases personally may not become too burdensome to the members of the visiting staff, the following system has been employed with great benefit.

If there are four visiting surgeons, one treats all cases that come to the hospital directly, *i. e.*, without being referred to the service of any particular surgeon, which are admitted from the first to the seventh of each month inclusively. The second surgeon treats all that are admitted from the eighth to the fifteenth inclusive. The third treats those that are admitted from the sixteenth to the twenty-second inclusive, and the fourth surgeon those admitted from the twenty-third to the end of the month.

If the staff contains three surgeons, then the periods are from the first to the tenth inclusive; from the eleventh to the twentieth inclusive; from the twenty-first to the end of the month inclusive.

If there are but two members of the surgical visiting staff, then the period should be during the first and second half of each month.

Each surgeon can then be prepared to respond to *emergency calls* during his active period. He can arrange his other work accordingly. During the time he is not on active duty he can complete the treatment of the cases admitted during his active period. He can operate on the cases referred to him personally and those sent to the hospital by himself. This plan greatly reduces the wear and tear, and still the

service remains continuous and enables the surgeon to establish a reasonable system, and at the same time the patients can be certain of competent care. At this point it may be well to state that many surgical hospitals or surgical departments of general hospitals suffer greatly from the fact that a great proportion of all acute, and especially of all emergency, cases are first placed under the care of inexperienced house officers, and that in many instances the most important work of making a diagnosis is left to these young men of considerable learning, little knowledge, very slight experience, and scarcely any wisdom.

Every patient, whether he enter as an emergency case, suffering from an acute or from a chronic disease, should have the benefit of an independent, unbiased physical examination by the visiting surgeon. In order that this may not make the service of the resident staff unattractive, it is well to have the admission of every patient at once reported to the senior member of the resident staff, whose duty it is to visit the patient immediately, write a careful history, make a systematic general and special examination, and make a diagnosis, which is recorded, not on the history sheet, but in a private record kept by the resident, in which he places, opposite the number of the patient's history, his own diagnosis, and, later, the diagnosis of the visiting surgeon, and still later the final diagnosis as completed during further observation, at the operation or at the necropsy.

This plan would eliminate errors in diagnosis to a very great extent, because the examination must then be independent and thorough, both by the chief and by his assistant, because anything which either may overlook will become a matter of record, and neither the chief nor his assistant can afford to have a record of an undue number of errors in diagnosis. Moreover, a reputation for careful examinations and accurate diagnosis is an important element in the successful organization of a surgical hospital, because the diagnosis is usually confirmed or disproved by the operation, while in the department of internal medicine this can be done positively, as a rule, only in cases which later come to necropsy.

In connection with the discussion of the care of surgical emergencies it should be stated that the hours of duty of the house staff must be so arranged that there is always some one prepared to answer an emergency call, either in connection with patients that are already in the hospital or those that are to be admitted.

In every case the senior member of the house staff should care for the immediate wants of the emergency cases, and in his absence from the hospital the one next in order as regards the period of service.

Each resident should spend one hour a day out-of-doors, and it is well to have a regular schedule of evenings off duty, but the service is much better if too few evenings are granted than if these are too numerous.

If the members of the resident staff are given too much time off duty, they soon acquire outside interests and cease to carry a due amount of responsibility concerning their patients in the hospital.

In case an emergency or a serious operation occurs just before it is time for a member of the resident staff to be off duty, his personal or social engagements should not interfere with the best interests of the patient. If his junior cannot perform the necessary work as well, then the social engagement should be abandoned and the patient cared for precisely as would be the case were the assistant in private practice and the patient his personal patient.

A bulletin board should be provided at a convenient point, with a sliding register indicating which members of the house staff are in and which out, and a record should be kept by the clerk in the office indicating the time of departure and the time of return. Before leaving the hospital the senior assistant should inform the junior, and vice versâ. Such a system does not involve much trouble, and it is of great benefit to the service.

Methods of Electing Members of the Surgical Staff.—The most satisfactory results can be obtained if the plan is followed which has been employed in the large hospitals connected with university clinics in most of the countries in continental Europe. When a vacancy occurs in the head of a department, the other heads of the departments recommend to the governing board two or three names of men whose eminence has been thoroughly established by their scientific research and clinical work as assistants to great masters, under whose direction they have served at least five, and often as long as ten, years. These names are presented as first, second, and third choice. The governing body usually selects the first choice, but may select either of the other two candidates.

The result of this system insures for the head of the department a man of undoubted ability.

He then proceeds to organize the staff of his department according to his own ideas, selecting his own chief assistant, and, with his aid, the remaining members of his staff. He himself has been selected because of his especial qualifications, and must necessarily inspire his assistants with the same spirit and desire for attaining excellence.

In our system he would occupy the position of visiting surgeon, who would control the entire surgical department in a hospital of moderate size, or he might control only a definite portion of the surgical department of a larger hospital.

The assistant visiting surgeon would occupy the position of the first assistant in a German clinic. He should consequently be a surgeon with from three to five years' practical experience as assistant in an inferior position.

The resident surgeons would correspond to the third, fourth, fifth, etc., assistants in European clinics.

Methods of Election of Residents.—In the election of resident surgeon there should be an educational qualification required for eligibility:

1. The applicant must be a graduate from some recognized medical school, and he must have passed the State examination, which will entitle him to practice medicine and surgery.

2. He must be of good moral character.
3. He must establish his practical fitness for the position.

Too much importance cannot be laid upon this point, because without it the service is sure to suffer severely sooner or later. A good method for establishing practical fitness for the work consists in choosing members of the resident staff from persons who have served for a period of three to six months in the capacity of externes. In this way only those whose service has proved their qualification can hope to receive appointment as residents, and this in turn serves the purpose of greatly improving the externe service.

In the future there must be developed more and more a tendency toward the organization of hospitals of moderate size in every city and town. In these institutions there will probably be from thirty to one hundred, or, at most, one hundred and fifty surgical beds. The following diagram of authority will represent the ideal organization of the surgical staff of such a hospital:

1. Visiting surgeon—in control of the entire department: continuous service; period of service not to exceed twenty-five years.

2. Assistant visiting surgeon—in control of entire department during vacation of visiting surgeon. First assistant in all important operations. In charge of night work and emergency cases when the visiting surgeon is not available. Continuous service. Period of service not less than five nor more than ten years, appointed by visiting surgeon. Qualifications: must have served as externe and as resident surgeon.

3. Resident surgeon—one for every thirty patients: serves as second assistant for a period not less than one and one-half nor more than three years.

If the service contains more than fifty beds, there should be a first and second resident, etc., the service being divided into as many portions as there are resident surgeons, and with the completion of the service of the first resident surgeon, the second should he advanced to the vacant place and the third to the second, etc., and the vacancy in the lowest service should be filled by a newly appointed man.

These residents should be responsible to the assistant visiting surgeon, and through him to the visiting surgeon.

Qualifications.—These men should be graduates in medicine from some recognized medical college. They should have successfully passed the State Board of medical examiners. They should have served satisfactorily in the capacity of externes for a period of at least three months, and, better, six months. They should receive their appointment from the visiting surgeon, who should take the advice of the assistant visiting surgeon, based upon his observation concerning the quality of service rendered during the period of probation in the capacity of externe. The positions of externes may properly be filled by competitive examination.

The duties of the resident surgeon should be those of second, third, fourth, etc., assistants. They should carefully record the histories,

make careful examinations of the urine, blood, excreta; assist in the preparation of patients for operation. Assist in operations and dressing of patients after operations. They should carry out the after-treatment under the direction of the assistant visiting surgeon.

4. Externes—each resident surgeon should have one or two assistants, serving for a period of three, four, or six months. These young men should be recent graduates or senior students in some recognized medical school. They should serve as clinical assistants to the resident surgeons, without responsibility. They should not be permitted to administer any treatment independently.

This general plan must result in as nearly a perfect organization as is possible under any given condition, because it contains all the elements which are employed in other successful human undertakings. The supply for recruiting the externes always exceeds the demand, and from these in turn the vacancies which occur in the resident staff can be satisfactorily filled. Among the relatively large number of residents, one is sure to find an extraordinarily capable man once every five to ten years to take the place of the assistant visiting surgeon, who, in turn, becomes the visiting surgeon in some other institution.

If there is an out-patient department, this may be placed under the care of the assistant visiting surgeon, who may choose his assistants from the resident and externe staff. This makes the out-patient department permanently subordinate to the hospital proper.

Hospital Conveniences.—It is important not to overlook certain elements which have an important bearing upon the surgical organization of hospitals, which in themselves really belong to the general administration and construction of hospitals. The element of competition has come to be of great importance in the successful organization.

In order to secure a satisfactory organization, the hospital must furnish suitable facilities and conveniences at an expense which will make the service available especially to the very large middle class of the population, which is the most important class to be considered, not only because of its numeric significance but also because the world's work is done by this class, and because the surgeon's income depends upon this class.

In order to accomplish this end, the hospital should be so planned that the greatest amount and the best quality of surgical care and comfort can be given to the greatest number of surgical patients with the smallest expenditure of money. In order that this may be accomplished, the hospital should be planned in a concentrated form, every portion of which has been carefully considered with the view of securing the conditions just mentioned.

The institution should contain all the utilities required, but they should be so arranged as to secure the greatest possible amount of service in the smallest possible amount of space.

In comparing the various existing hospitals in this country, statistics show that for conveniences that are approximately equal there is a very marked difference in the initial expenditure of money.

The two extremes may be found in two institutions which have been completed very recently, each containing every convenience and comfort that can be desired, both being constructed so as to be fireproof

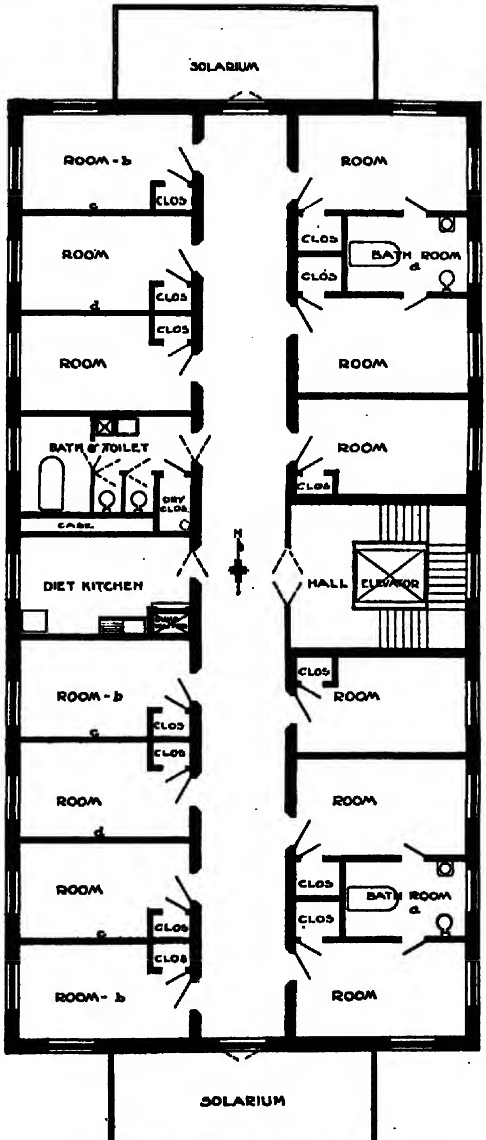

FIG. 544.—TYPICAL FLOOR FOR A MANY-STORIED HOSPITAL.

in every detail, except doors and floors and window-frames, which need not be fireproof, from the point of safety. In both cases every room and ward has windows exposed to sunlight. In fact, any surgeon examining either institution would consider every detail in itself as

nearly perfect as one might wish. Each of these two institutions accommodates sixty patients. There is, however, this difference: one was constructed at an expense of $48,000, while the other cost $1,000,000, or a little over twenty times the first amount. In one case it costs $800 to house each patient; in the other case, $16,000.

This has an important bearing upon the subject, because an appreciation of these facts will make the surgical organization of a hospital possible in any town or city in this country.

In order to secure an economic, convenient, and efficient form of construction, it is well to adhere to the principle contained in the accompanying figures, representing hospital plans, which will admit of indefinite expansion.

It will be seen, from Fig. 544, that this general plan places all parts of the hospital at the shortest possible distance from the service room, containing the diet-kitchen, medicine closet, ice-box, etc. It also places the general bathroom conveniently. The elevator is centrally located in a compartment entirely away from the hall, so that it causes no disturbance, and as this space is separated from the general hall, each floor is a unit in itself. This is a very important matter, especially if several surgeons are active in the same institution, because it is possible in this way to group the patients of each surgeon on a different floor and thus reduce the confusion incident to multiple authority to a minimum.

If it seems desirable to provide baths in connection with the rooms, this can be accomplished as shown at *a*; or the rooms may be arranged without this convenience, as shown at *b*.

Again, if it seems desirable to have wards in place of private rooms, the partitions marked *c*, *d*, may be left out. The space occupied by two rooms will then accommodate four ward beds. A single room may, of course, at any time be changed into a small ward by the introduction of an additional bed.

It is well, ordinarily, in all surgical hospitals, with the possible exception of the large municipal institutions, to have none of the wards planned for more than six beds, because of the greater privacy and comfort afforded to the patients; because it facilitates the classifying or grouping of patients suffering from similar diseases, and because it makes it possible to place the patients belonging to the various surgeons in separate wards, thus preventing unnecessary friction.

The advantage of placing patients suffering from similar diseases in the same ward is evident; since their care and treatment and diet must be similar, there will be less jealousy between the patients, and the care of the assistants and nurses can be more readily systematized.

Fig. 545 represents an ideal arrangement for the operating department for a surgical hospital of moderate size.

A study of this plan, for which I am indebted to Mr. M. J. Sturm, hospital architect, will show that it contains every desirable convenience, with perfect lighting, without the sacrifice of an unreasonable amount of space.

The various surgeons can readily arrange their days and hours for performing operations so that there will be no conflict. In case an emergency operation should occur during the regular operating hour of another surgeon, the second operating-room can readily be utilized for this purpose.

In case it should become necessary to give an anesthetic to two patients at the same time, one could be given in the anesthetizing room and the other in the operating-room or in one of the recovery rooms.

This department should invariably be located upon the top floor of the building, in order to prevent disturbance to the remaining patients in the hospital.

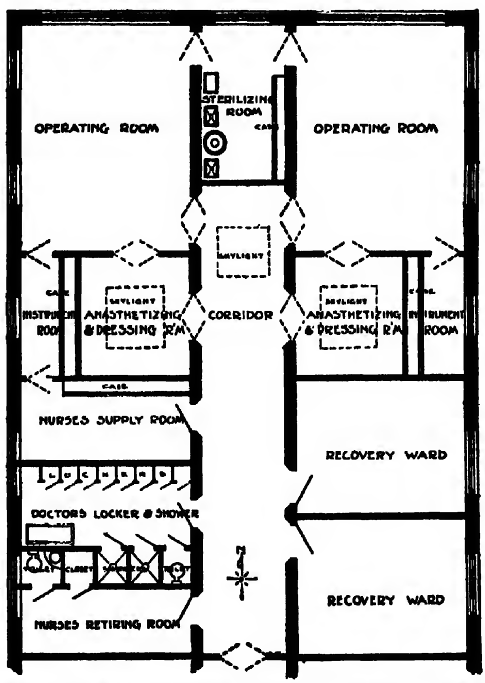

FIG. 545.—OPERATING DEPARTMENT FOR A SURGICAL HOSPITAL OF MODERATE SIZE.

Recovery rooms on this floor have been found to reduce the annoyance to the patients who are in the hospital and have already been operated upon, as well as to those that are waiting, to a very marked extent, because the remaining portion of the hospital is kept free from the disturbance of noisy patients recovering from the anesthetics, as well as from the disagreeable odors of the anesthetics.

Operating-room.—The accompanying plan (Fig. 545) shows in a a very concentrated form every convenience desirable for the operating department for a hospital containing not to exceed two hundred surgical beds. For a very small hospital, one-half the accommodations contained in this plan would be quite sufficient.

This plan provides for a building extending north and south, giving the operating-rooms proper a superb diffuse north light, which may be further augmented, if desired, by the addition of skylights also directed entirely toward the north. All the other rooms are supplied with sunlight, either from the east or the west, except the anesthetizing rooms, which have large skylights.

The lighting of the hall is in no way impaired by utilizing the north end for a sterilizing room, because of its location between the two operating-rooms, for here again a large skylight can be employed.

The instrument rooms are large, well lighted, and convenient.

The surgeons' dressing room, with toilet, shower-baths, and lockers, as well as the nurses' retiring room, are conveniences of great practical value.

All the doors are double swinging, in order that they will remain closed and will permit the passage of surgeons and nurses without the necessity of being touched by the hand.

One of the most important features is the recovery wards, which afford more comfort to the remaining patients in the institution than any other convenience. At the same time the patients who have just been operated upon profit greatly by this convenience, because they can in this manner receive the especial care they require from especially experienced nurses, and the house surgeons can conveniently observe their progress by visiting this department repeatedly during the day of the operation. Again, this department is entirely isolated from the remainder of the house, not only by the fact that it is located on the top floor, but by the addition of properly placed swinging doors in the hall.

Surgical Instruments.—It is best to secure a supply of instruments which will suffice for performing the operations required in the relief of the more common emergencies, but it is quite unnecessary to secure a very large number of instruments, and the expenditure of great sums of money in the purchase of expensive new and untried instruments is quite unnecessary.

There should be a fair supply of the instruments used in every-day surgical work, such as scalpels, scissors, hemostatic forceps, dissecting forceps, saws, probes, sounds, tracheotomy and intubation instruments, catheters, retractors, specula, needles and needle-holders, chisels and curettes, hypodermic and exploring syringes. In case an additional instrument is needed, this can readily be obtained in time for use.

The best surgical work is being done with few instruments.

At this point it may be well to direct attention to two points in the organization of the surgical service which, if adhered to, must result in much benefit: First, every member of the staff should adhere absolutely to his schedule regarding operating hours and visiting hours. This will facilitate the entire service enormously, and it will reduce the general wear and tear to a corresponding extent. Second, a register should be kept of appointments for operations at irregular times, in which the appointments should be made in the order in which applica-

tion is made for permission to use the operating-rooms outside of regular operating hours. Unless this plan is adhered to, there is invariably an endless amount of confusion in this department, and this is certain to produce unsatisfactory results. A reasonable time should be allowed for doing the operation scheduled to begin at a certain hour.

Any surgeon who will not adhere to these two conditions should not be permitted to remain upon the staff containing more than one active surgeon.

Conferences.—In order that any surgical organization may be successful, it is absolutely necessary to have conferences of the staff from time to time, in order that unsatisfactory conditions existing in any individual department may be carefully adjusted. Much progress can be made in this manner and nearly all of the most annoying drawbacks can usually be eliminated in this way.

Signing of Documents.—It is well to have a definite plan regarding the signing of certificates of various kinds, such as death certificates, certificates of personal injury, of refusal to submit to operation or other form of treatment, certificates stating the time the patient has been prevented from performing the usual work, or those stating the probable time of his disability in the future.

The senior house surgeon should perform this service. He should always keep a copy of the certificate and, except on rare occasions, when a lack of time prevents this, he should read the certificate to the visiting surgeon before delivering it. Although this consumes a little time, the entire time consumed is much less than would be required to undo one blunder which may occur if this precaution is not systematically carried out. The approval of the visiting surgeon can be obtained by telephonic communication in case the document must be delivered before the next visit of the visiting surgeon at the hospital.

In writing histories of patients who arrive in the hospital in a serious condition, either as a result of a personal injury, an assault, or from any other cause, it is most important that the house surgeon whose duty it is carefully to take and record the history be impressed with the importance of the utmost accuracy. If the data must be supplied by others, it is important to note their names. It is best to secure the name without laying special stress upon this fact, and then to be careful to note the full name and address before dismissing the informant. A small proportion of persons may be unwilling to be placed on record concerning what they know regarding such matters if one approaches them in a formal manner at once, before they have told their story. It is well to review the statement, especially in cases in which the condition may be due to an assault or to criminal negligence. A few moments of properly directed attention at this time will frequently be of more value than weeks of labor later on.

These statements should, however, never be left on the bedside history boards, because great injustice may result from leaving such information open to the inspection of visitors.

The legal chapter (pp. 1180–1197) will, of course, deal fully with ques-

tions of a purely legal aspect, like the procuring of death-bed or antemortem statements.

It may be well to caution surgeons never to call in nurses as witnesses except in cases in which this is done to protect the hospital itself.

Too frequently great hardship is wrought to nurses who have innocently witnessed wills or statements, because they must later obey a subpœna at any time, without regard to the condition of the patient they may be nursing at the time their evidence may be required. This may result in great harm, not only to the nurse but also the patient.

It is practically always possible to find some friend of the patient who is willing to act as a witness, and the slight amount of time this consumes amounts to nothing when compared with the trouble which is caused by following the opposite course.

Ambulance Duty.—Everything pertaining to clothing and other objects which may have a bearing upon the circumstances which give rise to the patient's condition should be carefully noted, although facts may later be produced which will make all these unnecessary.

The same is true regarding the odor of the patient's breath at the time of admission.

The most common error in this direction comes from making a diagnosis of acute alcoholism because of the odor of whisky upon the breath of a patient brought into the hospital in a comatose or semicomatose condition. This is due to the fact that it is a common practice of friends or others who are with persons who are suddenly taken seriously ill to induce the patient to swallow some brandy or whisky, because they imagine a stimulant is indicated.

Patients suffering from apoplexy, cerebral hemorrhage, cerebral concussion due to traumatism, uremic coma, diabetic coma, illuminating or coal or sewer-gas poisoning, carbolic acid poisoning, or sunstroke have been mistaken for cases of acute alcoholism, because some misguided friend has supplied whisky which was detected upon the patient's breath upon admission to the hospital. In order not to make these errors in diagnosis it is well invariably to bear the fact in mind that the breath is laden with odors of alcohol, but to reserve the diagnosis until all the other more common causes of unconsciousness or semi-unconsciousness have been eliminated.

Uremia.—This can be most readily determined by securing a specimen of urine, if need be, with the catheter, and examining it quickly for albumin and tube-casts.

By adding the test for sugar, diabetic coma can at the same time be eliminated.

An ophthalmoscopic examination will show the presence of an albuminuric retinitis.

Cerebral Hemorrhage.—There is usually in this condition a difference in the position of the extremities on the right and left side and a difference in the pupils. The arteries are usually markedly hardened. Many of these cases suffer simultaneously from chronic nephritis.

Apoplexy.—These patients have the appearance of a distinct class of patients in which this condition is to be expected. They show a severe congestion of the head, and the sclera show a marked congestion. One can usually elicit a history from friends of former milder attacks.

Thrombosis of Cerebral Arteries.—In these cases a difference in the pupils is common, and there is usually a distinct cardiac murmur, indicating the presence of vegetations upon the valves or upon the endocardium.

Asphyxiation by Sewer-gas; Coal-gas from Furnaces or Coal Stoves; Illuminating Gas; Smoke in Case of Fire Formed from Burning Chemicals; from Escaping Steam.—In all these instances the surgeon has the advantage of a history accompanying the patient, which will, of course, facilitate the diagnosis. These conditions have been very perfectly described by DaCosta.[1]

Symptoms of Smoke Asphyxia.—The earliest symptoms of smoke poisoning are a feeling of suffocation, with ringing in the ears, nausea, headache, giddiness, and muscular weakness. At this point the skin and lips are livid, the eyes red and watering, the body and extremities cold and moist, and the pulse very weak and usually slow. In slight cases the respirations are rapid and deep, while in more serious cases they are very rapid and shallow.

In the more severe cases the patient is totally unconscious. The pulse is very weak and fluttering, or may be imperceptible at the wrist. The extremities are very cold. The pupils are dilated and fixed, and there may be an absence of conjunctival reflexes. The respirations are extremely shallow, with distinctly gasping inspirations and long intervals between the respirations. The face frequently twitches, and the limbs may show tremor or even spasms. The eyes are prominent and suffused. The face and extremities are cyanosed; the cold cyanosed skin is covered with sweat. There is usually froth about the mouth.

In the most severe cases the respiration has actually ceased, although the heart still beats. In these cases, besides an intensification of the symptoms already noted, there is involuntary evacuation of the urine and feces, and frequently bleeding from the nose and rectum.

Treatment of Smoke Asphyxia.—"When a surgeon on the fire ground assumes charge, if a fireman is brought out of the burning building unconscious from inhaling smoke, gas, or some irritant vapor, he should at once inquire of one of the officers of the fire department whether the building is filled with pure smoke, or whether the smoke is mixed with illuminating gas or irritating or poisonous vapors, and whether the smoke is hot or cold. If it is at a fire where a number of men are being overcome he should establish himself in an adjacent room to this building, where he can more satisfactorily carry out prompt means of resuscitation. Finally, each ambulance should carry, besides the ordinary emergency supplies, a can of oxygen, a bottle of vinegar, some dilute ammonia, and a number of mustard plasters."

When a man is slightly overcome with smoke, he will recover without any treatment after sitting a while in the fresh air. His hands

should be rubbed and his face dried. It is well to encourage the patient to drink hot water freely to stimulate the action of the kidneys and to induce vomiting if possible. Under no circumstances should whisky be given by mouth, as it prolongs the nausea and adds to the giddiness and headache. If the circulation is weak and a stimulant is needed, a hypodermic injection of $\frac{1}{100}$ grain of atropin or $\frac{1}{60}$ grain of strychnin should be given.

When a man is severely overcome with smoke, he should be laid upon a blanket, and active treatment should at once be instituted. Artificial respiration should be made immediately, and should be continued until he breathes properly and has been restored to consciousness. If oxygen is at hand, this should likewise be administered. The cold extremities should be actively rubbed, hypodermic injections of strychnin or atropin should be given, and a mustard plaster should be placed over the heart. The body and the extremities should be rubbed dry, after which he should be put to bed, covered with warm blankets, and surrounded with hot-water bottles. If the heart is weak and its beats are irregular, after the patient has been placed in bed in the hospital it is well to place an ice-water coil directly over the heart, but there should always be a piece of flannel between the skin and the coil, and the latter should be removed if the temperature becomes subnormal. He should at once be given an enema of warm normal salt solution or coffee. A hot bath is a very efficient remedy. Further treatment must be entirely symptomatic.

Retention of urine may require catheterization. Not infrequently there is a troublesome conjunctivitis, which is best treated by means of simple wet dressings of saturated solution of boric acid in water or by dropping a few drops of castor oil into the eyes.

Asphyxiation Due to Illuminating Gas.—Ordinary smoke principally tends to produce asphyxia, associated, of course, with a degree of carbon-monoxid poisoning. However, the great majority of modern buildings are supplied with gas for illuminating purposes, and during fires the piping is often broken by falling timber or walls, or in other ways, thus adding to the danger that of illuminating-gas poisoning to that of the ever-present smoke. Asphyxiation in which illuminating gas plays an important part is, therefore, of fairly frequent occurrence at fires. These cases of asphyxia are not uncommonly met with in cases of attempted suicide. They are also quite common in vicinities in which gas is commonly used as fuel in dwelling-houses.

Symptoms.—As a rule, the victims of gas are unconscious when brought from the burning building, or they may lose consciousness even after removal, which latter does not occur in simple smoke asphyxiation. Likewise, they do not recover consciousness as promptly as in the case of simple smoke asphyxiation.

The poisonous effects of illuminating gas are due to the combined effects of carbon-monoxid and certain heavier hydrocarbon compounds (ethylene, propylene, butylene, ethane, propane, butane, etc.) known as illuminants. The toxicity of gases of different manufacture varies con-

siderably, water-gas being relatively decidedly more toxic than coal-gas, probably due chiefly to the very much greater proportion of carbon monoxid which it contains.

The diagnosis in the great majority of cases is based primarily upon the circumstances under which the patient is found, the presence of a strong smell of illuminating gas removing all doubt as to the etiology. Even after the removal from the original surroundings, the breath usually has a strong odor of gas for a considerable period of time.

The clinical picture is distinctly that of a profound intoxication, possibly in part due to the substitution of carbon monoxid in place of the oxygen in the hemoglobin of the red corpuscles, but undoubtedly chiefly due to the direct toxic action of the carbon monoxid and certain hydrocarbon compounds upon the cells of the central nervous system, the effects in some respects being analogous to a profound anesthesia. The only diseases likely to be confounded with this form of poisoning are cerebral apoplexy and uremic coma. Should the physician not see the patient until the odor of gas has escaped, such a difficulty might arise. In both of these diseases the symptoms are fairly constant, while in coal-gas or water-gas poisoning they are apt to fluctuate, the patient frequently rousing for a time so as to answer questions intelligently, only again to lapse into unconsciousness, or he may be seized with convulsions.

When first seen, these patients are nearly always comatose, and usually remain in this condition for an hour or more after discovery. Prolonged coma, lasting several days and followed by recovery, is not at all unusual, and cases are on record in which the coma has lasted as long as eighteen days before death.

In addition to coma there is almost invariably fever of an extremely irregular type, varying from 100° to 104° F. or even higher. The pulse-rate is usually rapid, being seldom below 120. The respirations are usually increased to 30 or more a minute, but in exceptional cases may be decreased to three to five beats a minute.

Cyanosis may be marked, but is often masked by the presence of the carbon monoxid hemoglobinemia, which gives the skin a peculiar pinkish hue. During the stage of unconsciousness there may be convulsions of greater or less severity, and convulsive seizures may persist for several days. As the patient regains consciousness he may suffer from mental weakness, confusion of ideas, and loss of memory. However, in the majority of these cases, there is a fairly prompt complete recovery without sequelæ.

Evidences of pulmonary edema are very frequently present, and this complication is often serious. Death was said to be due directly to pulmonary edema in 5 of Pilcher's[3] 6 fatal cases.

Treatment.—The treatment must be the same in asphyxia from illuminating gas, whether this occur during a fire or by the inhalation of gas from an open gas-jet or leak or from coal-gas developed by a badly ventilated coal-stove in a closed room. In these cases more than in almost any other it is of the greatest importance that the treatment

be promptly instituted, vigorously executed, and persistently maintained.

He should inhale as deeply as possible, then blow out forcibly through a tube with a lumen of 2 or 3 mm. An ordinary goose-quill will serve the purpose. Then the patient should be permitted to rest for one minute, breathing naturally during this time, when he should again take a very deep breath and blow out through the same tube. If he does not regain consciousness, a stomach-tube should be introduced and the stomach should be filled with water at 105° F., this water should be siphoned out of the stomach and fresh water introduced and again withdrawn repeatedly. The stimulation from this procedure seems to be very beneficial, and it is likely that there is a considerable amount of excretion of waste material through the mucous lining of the stomach, which is removed in this manner.

After completing the lavage, from two to four ounces of castor oil should be introduced through the stomach-tube and left in the stomach, in order to further facilitate excretion.

He should also be given a subcutaneous transfusion of at least 1000 cc. normal salt solution at a temperature of 100° F., and one-fourth this amount of blood should be drawn from a vein. Direct transfusion of blood is probably even more valuable. Artificial respiration should be employed, with short periods of interruption, until the patient breathes fairly normally or until he dies.

It should be borne in mind that these cases do not die rapidly when in the fresh air, but that they will certainly live for some time, and that they may rarely die at all from a brief immersion in the gaseous atmosphere. The very bad cases of gas-poisoning in which the mortality is high are usually people taken from rooms in which they have been breathing a gas-laden atmosphere for hours. These cases should be transported to the hospital at the earliest possible moment.

Therapeutic efforts must be directed toward the elimination of the toxic agents and the meeting of special indications as they arise.

The first consideration is an abundant supply of good air. In this connection oxygen inhalations would seem to be indicated, and good results from this measure are reported by Pilcher[3] and others. In cases in which the respiratory rate is markedly decreased, artificial respiration should be especially resorted to and continued as long as necessary. Cases breathing only two or three times a minute have made perfect recoveries after prolonged artificial respiration.

The most effectual way of combating the toxemia is undoubtedly by the free use of normal salt solution intravenously, subcutaneously, or by means of enemas, as indicated in any given case. Thompson,[4] after analyzing the results in 90 cases, treated chiefly at the Presbyterian Hospital, N. Y., strongly urges primary phlebotomy, followed by intravenous injection of normal salt solution, in every case in which the patient is unconscious and the pulse vigorous. He believes that this measure should be carried out thoroughly, removing from fifteen to eighteen ounces of blood, and following this by infusion of at least

1500 cc. of normal salt solution. This should be followed by further normal salt solution, given subcutaneously or per rectum.

In the most desperate cases it may be justifiable to resort to bleeding and to the transfusion of human blood obtained usually from some near relative. It is claimed that whereas the infusion of normal salt solution brings about a distinct benefit, the benefit is likely to be but temporary, and that a much more prolonged favorable influence is obtained by the infusion of human blood.

Ice-water sponges should be employed when the temperature is high, in addition to the ice-water coil over the heart. They seem to exert a markedly beneficial influence as cardiac and respiratory stimulants, in addition to the effect on the temperature.

If chlorin, the vapor of nitric, hydrochloric, or sulphuric acid or ammonia has been inhaled to any extent, the man's life will be put in deadly peril from edema of the glottis, and it may be necessary to do an immediate tracheotomy. It is needless to say that such cases should be treated by artificial respiration and stimulation, as outlined above, and removed to the hospital at once.

If ammonia vapor has been inhaled, vinegar should be inhaled. A few whiffs of very dilute ammonia should be given after the inhalation of acid vapors, and in the case of Cl and HCl the best treatment is said to be the inhalation of steam.

If there has been exposure to the fumes of nitric acid, serious symptoms may not develop for some hours after the exposure.

Sewer-gas Poisoning.—The poisonous effects of the air of sewers, cess-pools, and privy vaults are due to hydrogen sulphid, ammonium sulphid, and other undeterminable gases, and to carbon dioxid and nitrogen. In many cases the asphyxiation is due solely to a lack of a sufficient quantity of oxygen, but the greater danger is due to the presence of the poisonous sulphids, and the possibility of their presence must always be kept in mind.

Symptoms.—When the asphyxia is due entirely to a lack of sufficient oxygen, the individual suffers at first from a sense of discomfort, followed by muscular weakness, nausea, headache, profuse perspiration, cyanosis, rapid or slow pulse, and labored respirations, with, finally, unconsciousness and the development of anesthesia. Respiration may cease entirely an appreciable time before the cessation of the heart's action.

Hydrogen Sulphid Poisoning.—When the gases are inhaled in a diluted condition, as when sewer-gas is inhaled, the condition is characterized by nausea, giddiness, cold skin, labored breathing, irregular action of the heart, severe abdominal pains, and, at times, convulsions or even delirium, with death by coma or in violent convulsions with tetany. In still greater dilutions the gas is said to produce sleepiness and later coma, death occurring without the restoration to consciousness.

Treatment.—The proper treatment of these cases must depend ultimately upon the true cause of the asphyxiation. Careful inquiry

on observation should be made as to the nature of the gas inhaled, especially in regard to the presence of poisonous sulphid.

In all cases the first consideration is an abundant supply of oxygen by inhalation. The patient should be removed at once to where he can have an abundant supply of fresh air, and artificial respiration should be maintained until the patient breathes properly, and, if necessary, until he has regained consciousness. As soon as the breathing becomes satisfactory, he should be wrapped in a warm blanket and taken at once to the hospital, where, on admission, he should be rubbed dry and put to bed, covered with warm blankets, and surrounded with hot-water bottles.

In cases of simple asphyxiation an enema of normal salt solution or of hot coffee should be given, and, further, the patient should be treated purely symptomatically.

In the presence of poisoning by sulphids, coma and other alarming symptoms are liable to persist for some time, and special efforts should be made to eliminate the poisonous substance from the body. The further treatment in these cases should be carried out along the lines indicated under *Illuminating-gas Poisoning.*

Back Draft.—When a building becomes packed with smoke, this smoke contains unburned combustible elements, and a sudden access of air will cause the smoke to take fire or explode, causing the dreaded and deadly back draft, which is responsible for many deaths among firemen. A single inhalation of the burning vapor may cause instant death, and, at the very least, one exposed to "back draft" will be badly shocked and scorched, with immediate danger from edema of the glottis, and for days will suffer from burns of the skin, with inflammation of the respiratory passages and eyes.

The treatment must be immediate, vigorous, and persistent, and corresponds to that which has been described under treatment for asphyxia.

In case of edema of the glottis tracheotomy must be performed at once, but the friends of the patient must be distinctly told that this will only overcome the obstruction due to the edema, and that it will not relieve the other injuries deeper down in the respiratory tract.

This is important because unreasonable friends and relatives will frequently refer the death, which may not be averted, by this step to the operation, instead of attributing it to the real causes.

Cases Suffering from Burns.—*General Considerations.*—There are few accidents which combine so many unfavorable elements as do burns and scalds. Not only does this apply to the immediate consequences as regards mortality of the more severe injuries, but it applies likewise to the late results, which are liable to be bad, owing chiefly to the formations of contractures at the site of granulating surfaces.

It is important to have the resident staff thoroughly trained to undertake the immediate care of burn cases the moment they arrive at the hospital, or as soon as they are taken in charge in case the institution supports an ambulance service; in order that this care should be

given intelligently, it is important that there should always be on duty a house surgeon who has acquired a sufficient amount of practical experience while on duty as externe or assistant house surgeon.

In this, as in all other, work it is of especially great importance that some definite system be developed in order that the treatment may be given promptly and systematically.

Treatment.—Treatment of simple, less extensive burns consists essentially in efforts to relieve the pain and in establishing the most favorable local conditions for the rapid repair of the tissue injury, and, above all, in securing the elimination of poisonous products which have accumulated in the tissues as a result of the destruction due to the sudden application of excessive heat. Pain is best relieved by the application of some form of dressing which will protect the part from exposure to the air. Strict asepsis is imperative, in order that the processes of repair can proceed without the complicating presence of a secondary infection.

The above indications are met by the establishment of strict cleanliness and the application of mildly antiseptic substances, such as Carron oil, picric acid, the various antiseptic powders, zinc oxid ointment, etc. In the presence of infection moist antiseptic dressings, such as saturated solution of boric acid with the addition of alcohol, three parts of the former and one part of the latter, give the most satisfactory results.

Apparently, the best results have been obtained in cases which were immediately immersed in a bath of water at 98° to 100° F., the water being renewed frequently enough to remain pure. The entire body may be immersed, only the head protruding. The body should be supported by a gauze sling, and the bath-tub should be covered by a thick sheet to prevent drafts. This treatment can be improvised in any hospital by using the ordinary bath-tubs, or by using any one of the many forms of portable tubs which are in use, but it is, of course, more convenient to have baths especially arranged for the treatment of these cases.

Aside from the local treatment, cases of the more extensive burns require, during the first stage, treatment directed toward combating the shock. In this connection the pain must be controlled by the use of sufficient quantities of morphin. Normal salt solution should be freely given per rectum and subcutaneously. There is no form of treatment more useful in these cases than the immediate use of subcutaneous transfusions of normal salt solution in quantities up to 1000 cc. every eight hours in these cases. It serves to supply the necessary fluid to fill the blood-vessels, it dilutes and eliminates the poisonous substances in the tissues, and it relieves the patient from taking nourishment by the mouth until the lining of the alimentary canal has recovered sufficiently to be able to take up, in part at least, its physiologic function. Strychnin, adrenalin, and other stimulants may be used as indicated.

During the second stage meningeal congestion may be relieved by the local application of cold. Every effort should be made to aid

in the elimination of toxic materials, chiefly by the free use of water internally. Other conditions must be treated symptomatically.

During the third stage it is essential that there should be free drainage and no absorption from the suppurating surfaces. Liquids should be given freely. Nutrition should be maintained at the highest possible level, although the problem of nutrition is often complicated by the presence of duodenal ulcers or an acute enteritis. Great care should be taken not to give any food by mouth until the condition of the patient indicates that food can be assimilated. If food is given before this time, it will decompose, and the products of decomposition will be absorbed, which will further add to the burdens resting upon the overworked organs of elimination.

Sudden Insanity.—In case of sudden insanity in a patient who has been brought to the hospital for the treatment of some other lesion, the resident surgeon should first protect the patient against the danger of suicide during a paroxysm of mania. This can be accomplished by placing the patient in a room with barred windows, with which every hospital should be provided, or in an isolation room similarly arranged. It is equally important to protect the other patients against being injured or frightened by the insane patient. This can be most readily accomplished by placing the patient in an isolated room kept for this purpose, or by placing the patient under the constant care of a special nurse, who should never leave the room without being relieved by another nurse. In case these precautions cannot be taken, it is best to adjust a restraining apparatus which will keep him comfortably restrained in his bed until he can be removed to an asylum. When these arrangements are being made, the relatives or friends who are responsible for the patient should be notified, in order that they may take the responsibility of the patient's care.

If the patient has undergone an operation or is under treatment for fracture or for any other injury, steps should be taken at once to prevent the patient from doing anything that might interfere with the normal progress of the surgical aspect of the case. It may be necessary to keep the patient in the hospital for a considerable period of time until it will be safe to remove him to an asylum. The sooner this can be done, the better it is usually for the patient and his friends, as well as for the surgeon and the hospital, because of the better facilities for treating the insane in hospitals or asylums especially organized for this purpose.

In Cases of Murder or Suicide.—In cases of attempted murder or suicide the surgeon in attendance is liable to be called upon to give testimony in regard to facts concerning the patient's condition which may come under his observation, and it is desirable that accurate data regarding all observable findings should be kept as part of the case record. In addition all data should be obtained from the patient or others having a knowledge of the case which might aid the surgeon in making a correct diagnosis. In order to obtain a correct conception of the form and scope of this portion of the records which should be

kept, it is well to follow the principles laid down in the legal chapter of this work.

Thus, in gunshot injuries it is important that one should, if possible, learn the direction from which the shot was fired and also such data as may be obtained regarding the character of the weapon, the caliber of the bullet, and the distance from which it was fired. Accurate data regarding the location of points of entrance and exit of bullet wounds and any facts observed at the operation should be incorporated as part of the permanent case record, together with all the facts pertaining to the operative procedures themselves.

In injuries the result of stabbing or cutting or of blows by blunt instruments, it is essential that a record be kept of all facts which may help the physician to form a correct conception of the nature and extent of the injuries, together with a record of the directly observable data concerning the anatomic and clinical features of the injury. An accurate record should be kept of all the steps taken during any operative procedure, setting forth every detail. This should be written from the dictation of the operator at the time of the operation or immediately after its conclusion.

In cases of poisoning it is essential that every means be exhausted to ascertain the chemical nature of the poison employed. This may often be quickly and certainly accomplished by inquiring for the bottle or receptacle from which the poison was obtained, and thus a great deal of valuable time may be saved. It is, however, important to bear in mind the fact that deception is often practised by persons who pretend to commit suicide for the purpose of frightening friends or relatives by emptying a bottle containing poison and leaving the bottle in a convenient place, to be readily discovered by the friends.

The stomach-contents as removed by gastric lavage should be carefully saved for immediate examination, if necessary, and for subsequent examination, which may be required for medicolegal purposes. Additional data may be obtained by noticing the odor of the breath, stains of the mucous membranes, face, or clothing, and by examination of the urine and at times the feces.

In cases received in an unconscious condition, without an unmistakable history of poisoning, it is necessary to rule out such common causes of unconsciousness as alcoholism, uremia, apoplexy, or concussion of the brain due to falls or blows. This usually may be accomplished by a careful observation of the odor of the breath, the condition of the urine as regards the presence of albumin and casts, the condition of the extremities as regards paralyses, and the condition of the pupils.

Means and Methods of Transporting Patients.—In the larger institutions which are supplied with ambulance service the methods of transportation must depend upon the principles which have been so thoroughly established of late in connection with the handling of patients in military service, which will be found in the chapter on that subject. In smaller institutions and in hospitals in small towns which

are unable to maintain an ambulance service a most efficient system has been established in many parts of this country, which does not involve the expenditure of money on part of the institution and still serves to insure excellent results.

In every town there is some enterprising person conducting a livery stable, who will supply an ambulance with horses and driver if the hospital will insure patronage and will supply the house surgeon who is to accompany the ambulance in its journey to the hospital with the patient. The hospital should have a number of hampers containing sterile sheets, towels, blankets, and hot-water bags pinned in a thick sterile sheet, and this in turn in a sterile canvas bag. It should also keep in readiness a surgical bag containing the necessary instruments for performing any emergency operation, such as tracheotomy or intubation. It should contain hemostatic clamps, scalpels, dissecting forceps, catheters, needles, suture material, elastic constrictors, a stomach-tube, and an abundance of aseptic dressings and roller bandages.

In handling the patient especial attention should be directed toward the disease or injury from which the patient to be transported is suffering. In this service promptness of action, attention to detail, and gentleness in manipulation are the important elements, but, above all things, it is important to have everything in readiness at all times, in order that hurried, inadequate preparation may never be necessary.

With the use of proper stretchers, which are abundantly supplied by the various surgical supply houses, it is possible to carry a patient downstairs on ladders without danger of causing undue pain or producing injuries. It simply requires some experience and considerable judgment. The experience should be acquired by the resident surgeon during his service as externe or assistant house surgeon.

The same principles apply to all the manipulations which may become necessary until the patient has been comfortably placed in bed.

In removing the clothing, care should be taken not to increase the existing traumatism in fractures or contusions especially. In case of open wounds, it is important to prevent infection during the removal of clothing. The same is true in case of burns and scalds.

At this point it might be well to direct attention to the fact that great annoyance may be caused by the loss of articles of clothing and valuables belonging to a patient who is brought to the hospital in an unconscious condition. All articles of clothing should be placed in an individual locker, and a list of the various articles should be kept in the office, a carbon copy of this list being placed in the locker with the articles. All valuables should be placed in a sealed envelop containing a list of the various articles, a carbon copy of which should be kept on file in the office. These objects should be delivered only to authorized persons who have been identified, and who should give a receipt for the articles. Envelops containing valuables should be kept in the vault or in a fire-proof safe.

In conclusion, it might be well to direct attention to the most important features to be attained in the "surgical organization of a

hospital," if this is to be successful under the conditions existing at the present time:

1. There must be as nearly as possible a uniform system.
2. This must be extremely simple.
3. It must be sufficiently elastic to allow for the personal equation, which is always considerable in hospital staffs.
4. It must provide for continuous service.
5. It must establish definite lines of authority.
6. It must have the quality of permanency.
7. It must contemplate changes only after long-continued careful consideration.
8. It must avoid the development of a form of routine commonly termed red tape.
9. It must supply a plan by which those who are young in the service may obtain the necessary training to fill later the more responsible positions.
10. It must supply the best conditions for the individual case under treatment at any given time.
11. It must constantly strive toward supplying conditions which will provide the greatest good to the greatest numbers.

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